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RESEARCH STUDIES ON INVESTIGATION OF THE EFFECTS OF SLOW AND RAPID DECOMPRESSION UPON HUMANS AT 45,000 FEET

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May 31, 1963

FEDERAL AVIATION AGENCY CONTRACT FA-3082

Lockheed-California Company
A Division of Lockheed Aircraft Corporation
Burbank, California

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FOREWARD

A program on "Research Studies on Investigation of the Effects of Slow and Rapid Decompression upon Humans at 45,000 Feet" was performed under Contract FA-3082 with the Federal Aviation Agency at the Lockheed-California Company, Burbank, California, July 1, 1962 to May 31, 1963. The test portion of the program, involving actual decompressions of eight volunteer Lockheed employees, was conducted during January and February of 1963 at the Altitude and Space Environment Facility located at Rye Canyon, Saugus, California.

The principal investigator was assisted by four co-investigators: Thomas Cook, Winston Walker, John Parnell, and J. W. Wilson, Jr., M. D. In addition, the following persons from the Lockheed-California Company contributed materially to the program: Frank Cole, C. E. Gist, E. Gibbons, G. Hanff, M. Spotts, J. Reynolds, D. Oliva, and H. Sherwin from the Engineering Branch and A. Krivonos, M. D., Ralph George, and George Ray from the Medical Department.

The principal investigator was assisted by the following consultants: Reuben Straus, M. D., Director of Laboratories, Saint Joseph Hospital, Burbank, California, and W. Faeth, M. D., Neurophysiology and Electroencephalography.

SUMMARY

Tests were conducted to determine the effects of decompression from 8,000 to 45,000 feet at rates from 5 to 30 seconds on four pilot and four passenger subjects. Masks of several types currently in use in transport and business aircraft were worn or donned at varying intervals of exposure. Physiological measurements and cellular enzyme determinations were recorded in all tests, and performance and communication studies were conducted on the pilots. Results of the tests revealed inability of most subjects to complete all pretest instructions. Severe reactions or incapacitation of varying degree occurred in the three subjects exposed to the five-second decompressions. Convulsive movements occurred in two of the subjects who did not apply their masks for periods of about five to six seconds after reaching maximum altitude. Encephalographic changes, indicative of severe hypoxia, occurred in these cases between 17 to 40 seconds after the start of decompression. Performance and communications were adversely affected in all pilots undergoing decompression without wearing the mask; however, enzyme changes were nonsignificant in all except one passenger. ~~All passengers had difficulty in applying the mask properly.~~ The study confirmed the findings of other investigators in noting that unless 100% oxygen was inspired within 5 to 7 seconds after exposure to 45,000 feet, unconsciousness would occur at 13 to 16 seconds. The test emphasized the necessity for wearing an oxygen mask during all rapid decompressions to 45,000 feet and the need for improvement in oxygen disposing devices for passengers.

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INTRODUCTION

At the time the test program was proposed, very little information was available concerning the effects of slow and rapid decompressions to 45,000 feet on civilian pilots and passengers. Some studies had been performed by Comfort,[1] Luft,[2] Bryan,[3] Donaldson,[4] and Ernsting[5] on military and in a few cases civilian volunteers. However, most of the studies failed to realistically duplicate the precise decompression profiles and emergency situations that would exist in sudden loss of pressure in transport and business turbine-powered aircraft. The need for such additional studies was later emphasized by Blockley[6,7] in a number of excellent papers and reports.

The research program envisaged a comprehensive and objective study to explore many aspects of the critical problem precipitated by a decompression to 45,000 feet. The program was designed to specifically investigate the combined effects of decompression and hypoxia on the biological and performance capabilities of skilled pilots and to observe possible effects upon naive and unindoctrinated passengers. This originally was to be accomplished by exposing eight Lockheed volunteer subjects to a series of decompressions varying in rates from 5 to 50 seconds with dwell times at altitude of 0 to 15 seconds with and without the use of oxygen; exposures at maximum altitude with various masks in current use; pilot subjects exposed to unbalanced positive pressure breathing conditions; and by studying performance capabilities in pilots and mask-donning times in passengers; and as precisely as possible to simulate recompression rates of current certificated aircraft.

Instrumentation was to be available for the performance of electroencephalography; electrocardiography and oximetry; and measurements of respiration, galvanic skin response, body temperature, tidal volume, end expiratory gas analysis, and oxygen flow rates.

The subtle changes expected as a result of decompression exposures are believed to arise from submicroscopic morphological alterations, probably demonstrable by electron microscopy. Tissue samples for such investigations are not obtainable from human subjects. It is therefore believed that the alterations induced by this procedure may be reflected in changes in blood serum constituents. The intracellular enzymes are among the most sensitive biochemical constituents reflecting tissue damage or change. With respect to this, studies were to be conducted on serum concentrations of glutamic oxalecetic transaminase, glutamic pyruvic transaminase, and the lactic dehydrogenase enzymes.

Additional studies were designed to include the effects of decompression, hypoxia, and recompression upon voice and communication systems to include the following: basic speech production measures, which will be of some predicted value in intelligibility, physical investigation of the components of a given intercommunication system, and an intelligibility assessment. Test subjects would be volunteer Lockheed employees between the ages of 20 and 55 years. Each subject was to receive a complete physical examination and be qualified on an individual basis. Physical standards would be sufficiently flexible to include a number of persons with static disorders and marginal medical conditions, although those with serious or progressive diseases would be eliminated. The significance of this research was postulated as follows:

1. To extend our knowledge of the effects of very rapid and slow decompression to altitudes of 45,000 feet.
2. To evaluate the effects of decompressions of various rates and superimposed hypoxia of variable durations on the performance of crewmen.
3. Since intracellular damage on a mitochondrial level will result in increases in blood enzymatic levels, it is expected that subtle damage induced by decompression will be reflected in enzyme activity in the blood. The extreme sensitivity of erythrocytes to such damage makes it necessary to determine whether such increases in enzyme activity are due to intravascular red cell destruction or to damage of other tissues. The procedures recommended make possible the isolation of enzyme activity associated with the presence of hemoglobin and allow for a deductive estimate of the amount of damage that may have been induced in fixed tissues. Lactic dehydrogenase is also known to exist in a number of isoenzymic forms associated with globulin and albumin protein fractions. The appearance of these types, furthermore, have been specifically correlated with myocardial and hepatic damage.

4. To confirm and possibly extend our knowledge of the effects of decompression, hypoxia, and pressure breathing upon voice and communication systems.
5. To extend our knowledge of high altitude decompression upon persons with minor physical variations.
6. To determine the protection afforded by various oxygen protective systems during high altitude decompression profiles.

METHOD

Decompression profiles for several transport and business jet aircraft were obtained, but it was found unwise and technically impractical to duplicate the most severe emergencies which might occur. In addition, it was recognized that a test program of this type involved extreme hazards to the subjects and that the rates of decompression and exposure time at altitude without oxygen would require careful control. In accordance with these considerations and based upon additional recommendations by Blockley[8] in his final report to the Federal Aviation Agency concerning standardization and replication of decompression test profiles, a series of tests were designed which would minimize personal hazards and still meet the study objectives. These changes were discussed with responsible contracting agency personnel and were found to be acceptable. Accordingly, the following profiles were established:

TEST NO.	SUBJECT	ALTITUDE CHANGE (ft.)	DECOMPRESSION RATES (sec.)	DWELL Min.	TIME Sec.	MASK* APPLICATION (sec.)	DESCENT
1	Pilot	8 - 45,000 ft.	12	0	90	Mask Worn	JetStar
2	Pilot	8 - 45,000 ft.	30	0	45	5	707
3	Pilot	8 - 45,000 ft.	5	0	15	5	707
4	Passenger	8 - 45,000 ft.	12	0	15	5	JetStar
5	Passenger	8 - 45,000 ft.	30	0	45	Mask Worn	707
6	Passenger	8 - 45,000 ft.	30	0	15	10	707
7	Pilot	8 - 45,000 ft.	5	0	5	10	JetStar
8	Passenger	8 - 45,000 ft.	5	0	5	10	JetStar

*Time measured from start of decompression

Descent or recompression rates were in accordance with the following:

707		JetStar	
45,000 ft. -	0 seconds	45,000 ft. -	0 seconds
40,000 ft. -	32 seconds	40,000 ft. -	27 seconds
35,000 ft. -	50 seconds	35,000 ft. -	50 seconds
30,000 ft. -	122 seconds	30,000 ft. -	70 seconds
25,000 ft. -	158 seconds	25,000 ft. -	85 seconds
20,000 ft. -	212 seconds	20,000 ft. -	100 seconds
15,000 ft. -	255 seconds	15,000 ft. -	114 seconds.

The descent was stopped at 15,000 feet and the status of the subject determined. Descent rates to ground level were arbitrarily determined by the flight surgeon.

In actual testing, it was impossible to precisely duplicate the decompression profiles. The rates of decompression were in a range of 4.9 to 38.3 seconds; maximum altitudes varied from 44,295 to 48,000 feet; and dwell times at altitude extended to 84 seconds. Precise data for each test are contained in the following section on results.

The age range of the volunteer subjects was 30 to 47 years. All were interviewed by the Principal Investigator and fully informed of the objectives, methodology, and potential problems and hazards involved in the study.

Four subjects were highly skilled test pilots, three currently active in the Air Transportation Department of the Company. This involves piloting of small reciprocating engine aircraft transporting top-level Company personnel to various work and meeting sites. The fourth pilot was a production test pilot flying F-104 aircraft.

The four employees representing passenger types had varying degrees of previous flight experience. One had been a pilot during World War II and had used demand oxygen equipment. Two were private pilots without oxygen orientation. The fourth was a radio operator on B-17 aircraft during World War II and had used demand oxygen equipment. The latter also had considerable experience as a skin diver. Current occupations of the four passengers were purchasing agents, marketing engineer, and sales representative.

The subjects had completed a comprehensive physical examination for flying within six months of their exposure. The examinations included chest X-ray, electrocardiogram, blood count, and urinalysis. All subjects were considered physically qualified for flying and well able to participate in the test program. Minor physical variations included moderate obesity in two subjects, history of sinusitis and hepatitis in the past five years in one subject, moderate hearing difficulties, and other minor variations. The subjects were all highly motivated persons greatly interested in the study. They were extremely cooperative and tolerant and did not seem to be unduly disturbed by the delays required for application of the monitoring instrumentation. Several expressed displeasure at contributing blood specimens. A physical inspection performed on the day of the test run was designed to detect acute illness such as an upper respiratory infection, which would necessitate cancellation of the test. In no case was it necessary, however, to cancel a scheduled test due to an acute illness.

Because of the potentially hazardous nature of the test, extreme medical precautions were observed. Emergency medical supplies were stocked in the examining room located adjacent to the low pressure chamber. Additional drugs were placed in the chamber for use by the inside observer, if needed. Due to the location of the Research Center, a Company ambulance and attendant were available during all test runs. The emergency room of a large hospital 15 miles from the test area was alerted immediately before each run. A recompression chamber was available at a Navy base 50 miles away. The Principal Investigator, a qualified flight surgeon, personally supervised each test, assisted by one or more additional physicians. A skilled nurse assisted in monitoring critical instrumentation. Two highly experienced instructors alternated as inside observers, one in the main chamber and the second in the lock. Both instructors wore pressure vests to insure maximum safety.

Other key personnel consisted of two qualified low pressure chamber operators; instrumentation, electronics, acoustics, and mechanical engineers; and photographers. Key personnel were required to maintain check lists of detailed functions. The day before the first run, all operating personnel were assembled and emergency procedures outlined. It was decided that in the event of an emergency, the main pressure chamber would be recompressed to 30,000 feet in 12 seconds and to ground level within 60 seconds. An A-13A pressure breathing mask was available in the main chamber to be used as a backup in the event of a mask failure. An emergency was simulated the day prior to the initiation of the test program and all personnel and procedures checked out.

The tests were performed at a new altitude and space environment facility located at Rye Canyon, 27 miles from Burbank (Fig. 1). The facility includes a personnel test chamber, C-3, 8 feet high, 10 feet wide, and 18 feet long (Figs. 2,3). The chamber has space for 15 people, a capability of reaching 200,000 feet pressure altitude in 10 minutes, and can be decompressed through half an atmosphere in 1.0 seconds (Fig. 4). Seven windows provide clear viewing from all directions. Five 18" by 24" plug-in panels are available for convenience in providing instrumentation. A tested communication system links persons inside and outside the chamber. During the test procedure, all seats were removed and a regular pilot seat installed for the test run. Two regular passenger seats were used for the passenger exposures (Fig. 5).

Immediately adjacent to the personnel chamber is an entry air lock, C-2. The lock is 8 feet high, 10 feet wide, and 8 feet long. It can also be evacuated to 200,000 feet; however, decompression through one-half atmosphere can be achieved in 0.2 seconds. Four windows provide a clear viewing area. Very rapid decompression of C-2 is obtained by decompressing into a large accumulator chamber. Both C-2 and C-3 were controlled manually by chamber operators; however, the chambers could also be controlled automatically or programmed through any predetermined profile. During actual operation, an experienced observer remained in C-2 with the chamber evacuated to 15,000 feet. Had an emergency occurred, the C-2 would be decompressed and meet the personnel chamber during its recompression. Thus, within 12 seconds, two skilled observers, each wearing a pressurized vest, would be available for assistance to the test subject. Chamber C-3 has a large, easily removed end door. The test subject, if unconscious, could be removed through the opening in a supine position or on a rolling litter.

Biomedical monitoring included measurements of the following physiological parameters:

1. Heart activity through electrocardiography
2. Brain wave potentials through electroencephalography
3. Psychological stress through galvanic skin response
4. Respiration rate and tidal volume by an impedance pneumograph
5. Gas exchange studies through continuous analysis of percentage composition of nitrogen and carbon dioxide
6. Blood oxygen saturation through oximetry
7. Body temperature changes with a skin thermocouple
8. The rate of flow and temperature of the oxygen supplied to the subject's oxygen mask
9. The ambient temperature of the test chamber
10. The oximeter earpiece temperature.

The electrocardiographic electrodes were made in the Engineering Laboratory. They consist of 0.50 inch diameter wire mesh disks (Fig. 6). The disk is made of No. 80 mesh stainless steel screen, having 0.0055 inch diameter wire. The first series of electrodes had a fine, seven-strand, plastic-insulated lead wire soldered around the rim of the disk. The combination of materials was a potential source of artifacts. This was overcome by applying a coating of room temperature curing silicone rubber around the rim and onto the lead wire. The copper wire proved to be too delicate for repeated handling and, due to the silicone rubber cover, breaks were not readily discernible. The solder connection and copper lead wires were eliminated by using thermocouple junction welding techniques and welding a stainless steel lead wire to the disk.

The next step in the electrode development was to use the small lead cup type electroencephalograph electrode. These gave good results. The last electrodes used a dished, 0.50 inch diameter stainless steel disk with a stainless steel lead wire spot weld connection. Initially, the electrodes were attached to the subject with adhesive tape, but this technique did not seem to hold the electrodes securely in place. The last technique was to cement the electrodes in place with collodion. Burdick electrode paste proved satisfactory and did not dry as readily as laboratory paste. Artifacts caused by electrical interference were eliminated by relocating the wiring and careful grounding of the subject, the chair, and various components of the instrumentation system.

The electrode placement followed that developed in WADC Technical Report 58-453, "A System for Monitoring the Electrocardiogram during Body Movement."[9] The bipolar electrode placements were as follows: one electrode attached over the sternum at the level of the manubriosternal junction and a second attached over the vertebral column at the level of the lumbro-sacral junction, with a common electrode attached over the vertebral column at T-8 (Fig. 7). This electrode placement resulted in only minor disturbance in baseline shifting during movements of the subject's arms, head, and torso.

The electroencephalograph electrodes were of the lead solder, cup type, with a small hole at the apex for filling with electrode paste applied with a hypodermic syringe (Fig. 8). The electrodes were obtained from the White Memorial Hospital, Los Angeles, and had been used by them successfully in their Electroencephalography Laboratory. The electrodes were originally applied using their technique, but the results were not satisfactory. Resistance measured after electrode placement revealed readings well in excess of 10,000 ohms with considerable variation between electrodes. This exceeded the recommended maximum resistance level of 5,000 ohms or less as stated in The Handbook of Electroencephalography, by Robert S. Ogilivie.[10] A set of pin electrodes was obtained and applied in a manner recommended by the Laboratory Department of Saint Joseph Hospital in Burbank. They were used on several tests, but were unsatisfactory and did not reduce the resistance.

A measure of the psychological stress induced by the decompression was obtained through the galvanic skin response. The usual fingertip electrode could not be used because the subject was required to use his hands during the course of the test. Plantar electrodes, as developed in WADC Technical Note 58-284, "Development of Conductive Cloth Plantar Electrodes for Use in Measuring Skin Resistance," was utilized.[11] However, the electrodes used were made from a current-conducting aluminized tape (Fig. 9). The electrodes were held in place with elastic tape (Fig. 10). The placement of the electrodes on the instep of the foot is not completely understood, but seems to give good results. Studies have actually shown that the instep area has the least sweating of any section on the sole of the foot. Sweating due to stress occurs principally on the palm of the hand and sole of the foot. Some also occurs in the axilla, but is combined with thermal perspiration, so that the foot is the only logical area to be used. As the foot electrodes are sensitive to pressure and muscle movement, the subject's feet were elevated and the legs supported near the heel to minimize these effects.

Lung ventilation rate and volume were measured with an impedance pneumograph. An E & M Instrument Company assembly was modified in the laboratory for battery operation to facilitate its use with the Visicorder. Several electrode sizes, types, and placements were tried before obtaining a combination which gave a good signal (Fig. 11). The best results were obtained with the furnished electrodes held in place with adhesive tape in the midaxillary line of the chest at nipple level (Fig. 12). The test subject's output signal was calibrated while he was breathing in a spirometer.

The ventilation gas was constantly monitored and analyzed for carbon dioxide and nitrogen gas composition. By knowing the percentages of these two gases, the oxygen values can be calculated. The carbon dioxide composition was determined with a Beckman Medical Gas Analyzer. The nitrogen was monitored with a Waters Model AP-7 Nitrogen Gas Analyzer. Both of these instruments have a fast response and provide a means by which oxygen percentages can be calculated. Samples were obtained from a nasal tube placed beneath the nares (Fig. 13).

The blood oxygen saturation was measured with a single-channel ear oximeter. The detection cell is mounted on the flat portion of the pinna of the ear. The instrument was modified so that the galvanometer signal could be put into a remote readout meter located at the flight surgeon's station. The original remote readout meter proved to be troublesome. It was found that the high amplifier output required to drive the meter was a source of instability. A new and more sensitive meter was provided. The attachment of the oximeter earpiece proved to be a problem in that it was difficult to don an oxygen mask without disturbing the earpiece.

Body temperature was measured with a thermocouple mounted in the anterior part of the axilla and held in place with adhesive (Fig. 14). The junction of the copper-constantan wire was soldered to an 0.013 inch diameter disk of thin copper (Fig. 15). The temperature was recorded continuously on a pen write-out Minneapolis-Honeywell recorder.

Communication tests consisted of an examination of voice recordings made prior to, during, and after the decompression. The recordings were examined for voice quality changes and related effects. From the pilot subjects, verbalizations were obtained during the actual decompression period, while the passenger subjects were restricted to pre- and post-test samples. The test consisted of verbal production of numbers sequenced one through ten. As a further measure of interest, the subjects were asked to space these verbalizations at self-determined intervals of one second. This was done to survey the effects of the decompression on judgment of elapsed time. The verbalizations were recorded from two stations on a magnetic tape recorder (Fig. 16). One microphone was located above the subject's position, while an AIC system microphone was used by individual subjects. The pilots were required to continue counting through the decompression, stopping only to don the mask when required. The passengers produced a sample of verbalization prior to the decompression and again following descent to 15,000 feet.

A meaningful measure of performance was obtained for the pilot subjects through use of an aircraft control column placed under tension (Fig. 17). The pilots were asked to maintain the control column in a prescribed position throughout the test. When successful, a central green light signal was activated. When the column deviated more than one inch, two peripheral red light signals were activated. The aircraft was fitted with a microswitch which controlled the proper lights. A microswitch was also connected with a graphic level recorder to provide a tracing of the column positions.

In addition to the control column positioning, the pilots were required to apply their masks with one hand immediately upon the activation of a flashing light placed directly in front of and above their heads (Fig. 18). Also, a warning horn located immediately above their heads was simultaneously activated. The passengers were instructed to apply the mask immediately upon its presentation from an overhead drop box (Fig. 19). The box was controlled by a switch and opened at predetermined intervals. Light and warning horn signals were not used during the passenger decompressions. The passengers were instructed to sweep the mask to their face, covering the nose and mouth, and to place the harness over the head (Fig. 20). Photographic coverage of the tests was provided to more accurately study the reactions of the subjects and determine precise times for mask application.

Enzyme studies were performed on blood specimens obtained prior to and immediately after the decompression. A 20 cc. blood specimen was taken on each occasion. Five cc. were placed in each of two tubes for duplicate serum specimens and 5 cc. in two additional tubes containing an anticoagulant to provide plasma specimens. The blood was carefully drawn to avoid hemolysis. Syringes were siliconized and provided by the testing laboratory. The specimens were centrifuged and the serum separated from the red blood cells. The initial specimen was refrigerated and all specimens coded to eliminate identification of duplicates. Immediately upon collection and preparation of the post-decompression specimen, all samples were sent under refrigeration to the Straus Laboratory for analysis. The examination included determination of hemoglobin content, serum glutamic oxalecetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), and lactic dehydrogenase enzymes (LDH). In addition, lipid studies were performed whenever additional blood was available.

The equipment used during the study included the following items:

1. Firewel passenger mask with conical face piece, mask-mounted regulator, and quick-donning harness assembly, No. F-6022200, LCG-GL1329. This mask was used exclusively with a standard JetStar type dropout oxygen box and a 70 PSI oxygen regulator hose. The mask-mounted diluter demand oxygen regulator provided 3 to 5 inches of water safety pressure at altitude.

2. Crew masks:

   a. Aro-Firewel quick-don mask, No. 23808-200AL

   b. Sierra quick-don mask (Slick Airways configuration) No. 450-171

   c. Puritan quick-don mask (TWA configuration) No. 114020.

The various crew pressure-demand oxygen masks were supplied by a CRU-21 Automatic Pressure Demand Oxygen Regulator (MIL-R-25916). The regulator delivers automix normal or 100% oxygen by positioning of the automix lever. Automatic pressure is delivered by the regulator above 28,000 feet pressure altitude. Pressure delivered at 45,000 feet ranged between 8.2 to 12.8 inches of water with an average of 10 ±0.5 inches.

The intercommunication system in the chamber consisted of an AIC-10 dynamic-type system. Microphones used in all cases were of the dynamic type (USAF/M32, M100 or M101). The earphone (hearing aid type) was of the carbon type plugged into an adapter box to convert it to the dynamic system.

The two inside observers used the following equipment:

1. Canadian pressure breathing waistcoat
2. A-13A (MS 2200-1) positive pressure breathing mask
3. Pressure breathing backpack with F-2400 pressure suit regulator and high pressure gaseous emergency supply
4. AIC-10 headset with boom microphone.

The subject was contacted the day prior to the decompression and reminded of his appointment (Figs. 21-28). He was instructed to continue his general routine, obtain a good night's rest, eat his usual breakfast, and report to the research test center at 8:00 A. M. the following day. Immediately upon reporting, he changed into a loose fitting flight suit and reported to the examining room for a medical inspection by the flight surgeon. The procedure consisted of a brief review of the subject's health status, with emphasis upon acute medical problems; ear, nose, and throat inspection; blood pressure; heart, lungs, and abdominal examination (Figs. 29-33). Careful attention was paid to the subject's mental attitude and for evidence of anxiety. The information was recorded on a medical work sheet. The subject was then referred to a qualified nurse, who applied the following electrodes: EEG, ECG, GSR, skin temperature, impedance pneumograph, and nasal tube. The electrodes were checked with an ohmmeter for electrical resistance. Following this, the subject was thoroughly briefed by the flight surgeon in the test procedures and the reasons for the various measurements. A 20 cc. blood specimen was obtained, centrifuged, separated, and refrigerated in the manner previously indicated (Fig. 34). The subject was taken to the test chamber, C-3, and placed in the seat (Fig. 35). The ear lobe oximeter was applied and calibration of the oximeter, pneumograph, and gas flow meters performed. The impedance pneumograph was calibrated with the subject breathing into a Collins Spirometer (Fig. 36). The oximeter was of limited value, since it interfered with mask application and its use was restricted to two runs. A direct readout was provided at the flight surgeon's station for the EEG, ECG, oximeter, and chamber pressure (Fig. 37). An integrated, multi-channel recording of all pertinent data was made on the Visicorder and photographed for permanency (Fig. 38).

The flight surgeon coordinated the activities of the following persons: communication and performance engineer, photographers, inside observer, lock observer, chamber operators, and backup medical personnel. This was accomplished by a preliminary discussion of the flight profile, individual responsibilities, and emergency procedures for all possible events (Fig. 39). Each participant was asked to complete his check list. A preflight instrument checkout was then performed on the following equipment:

1. Flight surgeon's station
   a. EEG
   b. ECG
   c. Oximeter
   d. Manometer
   e. Stop watch
2. Instrumentation engineer
   a. EEG
   b. ECG
   c. Skin temperature
   d. GSR
   e. Pneumograph
   f. CO_2
   g. N_2
   h. Oximeter
   i. Chamber pressure
   j. Chamber temperature

An intercommunication check involving the flight surgeon, test subject, inside observer, lock observer, main chamber operator, lock operator, instrumentation engineer, communications engineer, and photographer was completed. The subject was then briefed by the inside observer as to precisely what was expected of him. He was shown the oxygen equipment and instructed in the application of the mask.

The personnel chamber and lock were secured and decompressed to 5,000 feet at a rate of 2,000 feet a minute. The chambers were then recompressed to 3,000 feet at a similar rate for an ear and sinus check. The chambers were then decompressed to 8,000 feet at 2,000 feet a minute and leveled for final checkout procedures. A last instrumentation check, repeating that above, was conducted, following which intercommunication between all subjects was again verified. The subject was instructed once again by the flight surgeon until it was certain he fully understood his duties. The photographer was advised to turn his lights on and start his cameras approximately 15 seconds before decompression. Camera coverage consisted of three cameras, each shooting from different windows. One camera was focused directly on the subject's face, a second provided an expanded view from the forward position, and the third recorded the events from the subject's left side.

Approximately 10 seconds prior to decompression, the subject began his countdown. This involved counting numbers from 1 to 10 sequentially at self-determined intervals of one second. In addition, the pilots were required to properly position the control column so that only the central green light would be illuminated. Decompression through the programmed profile was started following a ready signal by the flight surgeon. To assure the subject maintained an open airway and avoided breath-holding, the instrumentation engineer was given the responsibility of initiating the precise signal for decompression. This occurred within 5 seconds after authorization. Within 1 to 2 seconds after the initiation of the signal, the chamber was manually decompressed by the operator and the profile completed. The pilots were instructed to count throughout the entire test, except when donning the mask. They were required to apply and secure the mask with one hand and to maintain proper positioning of the control column at all times with the other one. They had been informed they could request immediate descent, either orally or by hand signal, should they wish to terminate the test. They had also been informed that the inside observer would apply the mask should they fail to do so.

The Firewel passenger mask did not contain a microphone; consequently, communications were monitored with a hand microphone until mask donning in all passenger tests. Following descent to 15,000 feet, the masks were removed, and the subjects were instructed to continue counting to permit comparison of the post-decompression verbalization with the pretest baseline. Since both hands were used in applying the passenger mask, no further performance testing was programmed. The mask-donning time, however, was recorded in each case.

In addition, the passengers were instructed to depress the automix lever located on the right-hand side of the mask from its 100% position to normal when passing through 30,000 feet during descent. The ability to perform this task was noted.

The chamber was leveled at 15,000 feet during recompression and the subject's general status established. Recompression to ground level at rates specified by the flight surgeon was then effected. Rates ranged from a maximum of 5,000 feet per minute for the pilots to 1,000 feet per minute for the passengers. Upon reaching ground level, restrictive attachments were removed and the subject returned immediately to the examining room. The lock and observer were kept at 15,000 feet when the main chamber was above this altitude.

Immediately upon returning to the examining room, a second 20 cc. blood specimen was obtained and prepared as described previously. The blood specimens were then transported in a refrigerated container to the Straus Laboratory for analysis. A final physical inspection was performed, duplicating all techniques used previously. The subject was questioned concerning his reactions to the test and these, plus the observations of the flight surgeon, entered on the work sheet. The electrodes were removed, and the subject was permitted to shower and change to street clothing. He was given the flight surgeon's business and home phone numbers and was instructed to contact him should any aftereffects occur. He was allowed to continue his regular activities for the balance of the day, being advised, however, not to engage in aerial flight, if at all possible.

On the morning following the test, the subject was contacted by phone and further reactions solicited. An additional examination was planned if indicated by the presence of symptoms. The work sheet was completed and the test considered concluded at this point.

RESULTS

TEST RUN NO. 1 - JANUARY 9, 1963 (PILOT)

SUBJECT:	E. C. P. - Production Test Pilot
AGE:	42
PREVIOUS EXPERIENCE:	Jet test pilot - 5,550 hours; qualified, positive pressure breathing equipment
MEDICAL HISTORY:	Experienced severe diarrhea one week prior to test
DECOMPRESSION PROFILE:	Sierra quick-don crew mask worn throughout test
	Initial altitude 8,000 feet - 0 seconds
	Time to reach 30,000 feet - 6.3 seconds
	Decompression time to 44,765 feet - 18 seconds
	Dwell time at altitude - 84 seconds
	Descent rate to 15,000 feet (JetStar rate) - 114 seconds
SUBJECT'S EVALUATION:	Experienced tightness and pressure in abdomen. Did not see warning light or hear horn.
OBSERVATIONS:	
Flight Surgeon:	Appeared to experience breathing difficulty with maximum pressure at altitude. Face congested and slightly cyanotic; held mask tightly; appeared to be in control of faculties at all times. Continued to count beyond ten on a number of occasions. Post-flight examination revealed moderate blood pressure rise over baseline.
Inside Observer:	Standard reaction to pressure breathing.
POST-FLIGHT EFFECTS:	None
MONITORING INSTRUMENTATION:	Instrumentation was mainly unsatisfactory due to malfunction of several critical items, electrical interference, and poor electrode attachment.

RESPIRATION

ALTITUDE (Feet)	RESP. RATE (Minutes)	AV. TIDAL VOLUME (Liters)	MINUTE VOLUME (Liters)
8,000	24.6	0.53	13.06
44,765	29.0	1.18	34.19
15,000	21.3	0.60	13.44

COMMUNICATION: The pretest mean duration between counts was 2.6 seconds. This was measured while the subject was breathing with the oxygen mask on, and the tendency was to allow the rhythmic respiration cycle to control the time between counts. Intelligibility was severely impaired by exhaled gas escaping around the poorly sealed mask. During and following the decompression, the associated noise resulted in an additional intelligibility decrement. The mean duration between counts decreased to 1.7 seconds following the onset of the decompression. The respiration cycle appeared to influence this duration more than the pretest instructions to maintain a one-second interval. Also, during the decompression, the voice pitch was noticeably raised.

PERFORMANCE: The performance task was not used with this pilot, although he appeared to function adequately throughout the test.

BLOOD CHEMISTRY: No significant changes in lactic dehydrogenase (LDH), serum glutamic oxalecetic transaminase (SGOT), and serum glutamic pyruvic transaminase (SGPT).

TEST RUN NO. 2 - JANUARY 17, 1963 (PILOT)

SUBJECT:	E. L. H. - Production Test Pilot
AGE:	30
PREVIOUS EXPERIENCE:	Jet pilot - 5,700 hours; qualified, positive pressure breathing equipment
MEDICAL HISTORY:	Not significant

DECOMPRESSION PROFILE:	Initial altitude 8,000 feet	- 0	seconds
	Time to reach 30,000 feet	- 15.4	seconds
	Decompression time to 44,835 feet	- 34	seconds
	Mask (Aro-Firewel) don time from start of decompression	- 7.2	seconds
	Mask don time from signal	- 3.8	seconds
	Dwell time at altitude	- 45	seconds
	Descent rate to 15,000 feet (707 rate)	- 255	seconds

SUBJECT'S EVALUATION: Experienced pressure build-up in mid-epigastric area. Denied difficulty in applying mask; saw the warning light, but did not hear the horn.

OBSERVATIONS:

Flight Surgeon: Contrary to instructions, subject released the control column at the decompression signal; required several seconds to apply and adjust mask; face was flushed; appeared to cycle his counting with respirations. Post-flight medical findings unchanged.

Inside Observer: Excessive leakage was noted around the nose and mouth area at pressure of 10 inches of water. Pilot held the mask tightly to his face after the decompression. During descent, when the pressure decayed, he removed his hand from the mask.

POST-FLIGHT EFFECTS: None. Complete flight physical performed the afternoon of the test with normal results.

MONITORING INSTRUMENTATION: EEG - No abnormalities

ECG - Baseline rate - 74/m

Prior to decompression - 100/m

Decompression (30 sec.) - 120/m

Altitude (75 sec.) - 150/m

Baseline (30,000 feet) - 74/m

Several premature ventricular beats during decompression.

RESPIRATION

ALTITUDE (Feet)	RESP. RATE (Minutes)	AV. TIDAL VOLUME (Liters)	MINUTE VOLUME (Liters)
8,000	24.8	0.40	9.92
44,835	22.7	2.73	61.97
15,000	8.5	0.76	6.46

COMMUNICATION: The pretest mean duration between counts was 2.1 seconds. The count was resumed at t + 12 seconds. From this point, the voice quality was badly distorted until an altitude of 30,000 feet was reached during descent. The distortion apparently resulted from difficulty in breathing against the oxygen pressure. From this point to ground level, the voice was fairly intelligible. The mean duration between counts following decompression was 2.0 seconds. No change in voice quality was observed.

PERFORMANCE: The subject maintained proper positioning of the control column at all times after the decompression, releasing the column only when donning the oxygen mask.

BLOOD CHEMISTRY: No significant changes in LDH, SGOT, & SGPT.

TEST RUN NO. 3 - JANUARY 28, 1963 (PILOT)

SUBJECT:	J. W. - Production Test Pilot
AGE:	30
PREVIOUS EXPERIENCE:	Transport aircraft - 3,000 hours; qualified, positive pressure breathing equipment
MEDICAL HISTORY:	Not significant

DECOMPRESSION PROFILE:

Initial altitude 8,000 feet	- 0	seconds
Time to reach 30,000 feet	- 2.0	seconds
Decompression time to 44,295 feet	- 4.9	seconds
Mask (Sierra) don time from start of decompression	- 8.0	seconds
Mask don time from signal	- 4	seconds
Dwell time at altitude	- 18.5	seconds
Descent rate to 15,000 feet (707 rate)	- 255	seconds

SUBJECT'S EVALUATION: Saw the warning light, but did not hear horn; light-headed and thought he would lose consciousness; aware of confusion during counting, but unaware of control column position.

OBSERVATIONS:

Flight Surgeon: Donned mask rapidly, but counted beyond 10. Did not position stick until ordered to do so. Appeared to have fully recovered at 25,000 feet during descent. Post-flight medical findings unchanged.

Inside Observer: Mask donning was fairly rapid after signal and without apparent difficulty. Subject appeared alert at all times. Observer did not hear warning horn.

POST-FLIGHT EFFECTS: Complained of giddiness after flight and felt "washed out" for several hours. Had lunch and rested with disappearance of "washed out" feeling; decided to fly small aircraft in the evening.

MONITORING INSTRUMENTATION: EEG (Needle electrode) - No abnormalities. Control record fair; no artifacts or abnormal wave forms. Record poor during decompression with numerous artifacts, but no abnormalities.

ECG	-	Baseline rate	- 68/m
		Prior to decompression	- 110/m
		Decompression (5 sec.)	- 120/m
		Altitude (15 sec.)	- 150/m
		Baseline (26,000 feet)	- 76/m

COMMUNICATION: The pretest mean duration between counts was 1.2 seconds. The voice quality was unchanged throughout the decompression, with good intelligibility. When the counting was resumed following the decompression, the subject departed from pretest instructions and continued counting up to twenty. The mean duration between counts following the decompression fell to 0.9 seconds.

PERFORMANCE: Prior to the decompression, the subject maintained proper position of the control column. Following the decompression, the subject failed to reset the column even though he was reminded to do so on three occasions by the flight surgeon. Finally, the inside observer pointed to the column, and the subject responded.

BLOOD CHEMISTRY: No significant changes in LDH, SGOT, & SGPT.

TEST RUN NO. 4 - FEBRUARY 12, 1963 (PASSENGER)

SUBJECT:	R. M. J. - Marketing Engineer
AGE:	37
PREVIOUS EXPERIENCE:	Reciprocating engine aircraft, World War II; small plane pilot - 1,000 hours; qualified in use of demand oxygen equipment
MEDICAL HISTORY:	Hepatitis and infectious mononucleosis, 1959
DECOMPRESSION PROFILE:	Initial altitude 8,000 feet - 0 seconds
	Decompression time to 48,000 feet - 10 seconds
	Mask (Aro-Firewel) don time from start of decompression - 6.4 seconds
	Mask don time from signal - 3.5 seconds
	Dwell time at altitude - 15 seconds
	Descent rate to 19,000 feet (JetStar rate) - 120 seconds
SUBJECT'S EVALUATION:	No difficulty except for pain in left ear at 19,000 feet.

OBSERVATIONS:

Flight Surgeon: Subject applied mask rapidly, but did not cover the nostrils. Lateral mask straps were positioned above the ear. Chamber was leveled at 19,000 feet at request of subject. Post-test examination revealed marked injection of the left tympanic membrane. Pulse rate increase of 14/m after flight.

Inside Observer: Passenger improperly positioned mask to cover mouth only resulting in nasal breathing of chamber air. Side straps were positioned above the ear rather than below the ear lobe, causing upward pulling movement at the lower attachment point of the mask, requiring the passenger to hold the mask against his face until properly positioned by the observer.

MONITORING INSTRUMENTATION: <u>EEG</u> (Cup Electrode) - Control record revealed a good tracing without abnormalities. During the decompression and stay at altitude, the record was obscured by movement artifacts for the first 10 seconds, after which 4 to 5 second slow waves (abnormal) appeared at 25 seconds, gradually slowing to 2 per second at 60 seconds, and disappearing in 90 seconds. This represents a reversible hypoxia effect.

<u>ECG</u>	-	Baseline	- 74/m
		Prior to decompression	- 140/m
		Decompression (12 sec.)	- 168/m
		Altitude (27 sec.)	- 180/m
		Baseline (6,500 feet)	- 90/m

COMMUNICATION: The pretest mean duration between counts was 1.5 seconds and fell to 1.2 seconds following the decompression. No differences in voice quality were observed for these two periods.

PERFORMANCE: The mask was donned rapidly following the signal with good coordination. When the mask was positioned on the face, it resulted in a poor seal, particularly around the nose.

BLOOD CHEMISTRY: No significant changes in LDH, SGOT, & SGPT.

TEST RUN NO. 5 - FEBRUARY 15, 1963 (PASSENGER)

SUBJECT:	P. D. - Sales Representative
AGE:	36
PREVIOUS EXPERIENCE:	Private pilot - 4 years; no prior oxygen equipment orientation
MEDICAL HISTORY:	History of sinusitis with nasal polyps and partial obstruction of one nostril
DECOMPRESSION PROFILE:	Mask (Firewel passenger mask) worn throughout test

Initial altitude 8,000 feet	- 0	seconds
Time to reach 30,000 feet	- 15.7	seconds
Decompression time to 44,295 feet	- 38	seconds
Dwell time at altitude	- 42	seconds
Descent rate to 15,000 feet (707 rate)	- 255	seconds

SUBJECT'S EVALUATION: Experienced lightheadedness at altitude. No other discomfort.

OBSERVATIONS:

Flight Surgeon: Did not appear to be in distress at any time. No apparent cyanosis or breathing difficulty. Was alert and responsive at all times. Post-test medical findings unchanged.

Inside Observer: No apparent difficulty noted.

POST-FLIGHT EFFECTS: Slight swelling and irritation of face in areas which were in contact with mask. No other after-effects.

MONITORING INSTRUMENTATION: EEG - Control record excellent with clear alpha rhythm at 12 to 13 cps. During decompression phase, 2 to 3 cps. slow waves noted after 20 seconds and between 30 to 35 seconds with normal findings thereafter. No definite abnormality seen other than that noted above.

ECG -

Baseline	-	84/m
Prior to decompression	-	96/m
During decompression (38 sec.)	-	108/m
Altitude (75 sec.)	-	136/m
Baseline (22,000 feet)	-	84/m

RESPIRATION

ALTITUDE (Feet)	RESP. RATE (Minutes)	AV. TIDAL VOLUME (Liters)	MINUTE VOLUME (Liters)
8,000	8.7	2.01	17.49
45,000	12.0	1.98	23.76
30,000	13.5	1.38	18.63
15,000	11.9	0.96	11.44

OXIMETRY

TIME (Sec.)	ALTITUDE (Feet)	O_2 SATURATION (%)
0	8,000	95.5
38.0	45,000	91.7
84.4	45,000	60.0
144.0	37,000	91.5
196.5	30,000	94.0

COMMUNICATIONS: The pretest mean duration between counts was 1.6 seconds, which decreased to 1.4 seconds following the decompression. No voice quality difference was observed.

PERFORMANCE: Hand movements appeared to be well coordinated throughout the test.

BLOOD CHEMISTRY: Borderline values for beta/alpha lipid ratios pre- and post-test runs. No significant changes in LDH, SGOT, & SGPT.

TEST RUN NO. 6 - FEBRUARY 21, 1963 (PASSENGER)

SUBJECT:	B. B. H. - Purchasing Agent
AGE:	47
PREVIOUS EXPERIENCE:	Private pilot - No prior use of oxygen
MEDICAL HISTORY:	Hypotension (106/70); mild bronchitis, left lung
DECOMPRESSION PROFILE:	Initial altitude 8,000 feet - 0 seconds
	Time to reach 30,000 feet - 19.6 seconds
	Decompression time to 44,845 feet - 37 seconds
	Mask (Firewel) don time from start of decompression - 10.6 seconds
	Mask don time from signal - 3.4 seconds
	Dwell time at altitude - 10.5 seconds
	Descent rate to 15,000 feet (707 rate) - 255 seconds

SUBJECT'S EVALUATION: Had moderate gas distention after start of descent. Discomfort in right ear at 20,000 feet, but did not request leveling of chamber. No other complaints.

OBSERVATIONS:

Flight Surgeon: Reacted well to decompression. Did not get the harness on completely. Face was congested and appeared to have slight ear distress at altitude. Did not respond to first several questions. Accidentally moved the automix level to normal position prior to reaching 30,000 feet. Post-flight medical findings unchanged, except for slight redness of right tympanic membrane.

Inside Observer: Subject appeared calm and reacted rapidly. Did not pull mask harness over his head completely and mask tended to ride up on face. Had to hold one hand on the mask. Except for inadvertent moving of the automix lever prior to instructions, no other unusual events occurred.

POST-FLIGHT EFFECTS: Ear responded to simple treatment. No other complaints.

MONITORING INSTRUMENTATION: <u>EEG</u> - Record poor, but revealed some 5 to 6 cps. slow waves at 40 to 45 seconds after decompression; balance of tracing normal.

ECG	-	Baseline	- 90/m
		Prior to decompression	- 112/m
		Decompression (30 sec.)	- 150/m
		Altitude (45 sec.)	- 156/m
		Baseline (12,000 feet)	- 96/m

RESPIRATION

ALTITUDE (Feet)	RESP. RATE (Minutes)	AV. TIDAL VOLUME (Liters)	MINUTE VOLUME (Liters)
8,000	20.7	0.28	5.88
45,000	11.6	1.36	15.72
30,000	10.0	1.76	17.55
15,000	33.4	0.83	27.69

COMMUNICATION: The mean duration between counts was 1.5 seconds and decreased to 1.2 seconds following the decompression. The intensity of the voice was noticeably decreased following the decompression.

PERFORMANCE: The mask was donned successfully following the signal, but again a poor fit on the face was obtained. Good hand coordination was demonstrated by the subject.

BLOOD CHEMISTRY: No significant changes in beta/alpha lipid ratios or in LDH, SGOT, & SGPT.

TEST RUN NO. 7 - FEBRUARY 22, 1963 (PILOT)

SUBJECT:	W. A. W. - Production Test Pilot (Jet)
AGE:	34
PREVIOUS EXPERIENCE:	Jet aircraft - 3,350 hours; qualified in partial pressure suit and pressure breathing equipment
MEDICAL HISTORY:	Labile hypertension

DECOMPRESSION PROFILE:	Initial altitude 8,000 feet	- 0 seconds
	Time to reach 30,000 feet	- 2.0 seconds
	Decompression time to 44,820 feet	- 5 seconds
	Mask (Puritan quick-don) don time from start of decompression	- 12 seconds
	Mask don time from signal	- 4.0 seconds
	Dwell time at altitude	- 6 seconds
	Descent rate to 15,000 feet (JetStar rate)	- 114 seconds

SUBJECT'S EVALUATION: Remembers having applied mask to face, but has no recollection of the other events until hearing the flight surgeon say "red lights" at approximately 25 to 30 seconds after decompression. States he required an additional 20 to 30 seconds to recover full capabilities. Experienced some pain in right ear after start of descent.

OBSERVATIONS:

Flight Surgeon: Reacted rapidly and applied mask to face, but harness did not completely encase the head. Approximately 14 to 16 seconds after the start of the decompression, head became flaccid, eyeballs momentarily turned upward and left hand dropped from the mask and jerked two or three times. Appeared to have recovered almost immediately thereafter, but did not attempt to position stick until 27 to 30 seconds after decompression. Over-controlled stick during initial attempts, but corrected and appeared to be in full control of faculties thereafter. Crystal flew off watch during decompression. Watch stopped at moment of decompression.

Inside Observer:	Did not place mask harness properly over head; however, mask appeared to seal adequately to the face. Loss of consciousness occurred approximately 13 seconds after decompression, but appeared to have recovered 6 or 7 seconds later.
POST-TEST EXAMINATION:	Systolic blood pressure elevated 18 mmHg.
POST-FLIGHT EFFECTS:	Felt "washed out" and cancelled flight scheduled for late afternoon. Recovered fully after adequate rest and had no complaints thereafter.

MONITORING INSTRUMENTATION: EEG - Extremely good record with 9 to 10 cps. alpha waves during control study. Seventeen seconds after decompression, 3 cps. slow waves appeared and persisted until 40 seconds, with normal findings thereafter. Post-decompression control record showed normal 9 cps. alpha waves. Record of slow wave occurrence coinciding with period of hypoxic confusion.

ECG -

Baseline	- 74/m
Prior to decompression	- 80/m
Decompression (5 sec.)	- 120/m
Altitude (10 sec.)	- 132/m
Maximum (35 sec.)	- 156/m
Baseline (10,000 feet)	- 78/m

RESPIRATION

ALTITUDE (Feet)	RESP. RATE (Minutes)	AV. TIDAL VOLUME (Liters)	MINUTE VOLUME (Liters)
8,000	31.6	0.56	17.70
45,000	21.6	1.80	38.88
30,000	45.5	0.21	9.33
15,000	44.8	0.26	11.65

OXIMETRY

TIME (Sec.)	ALTITUDE (Feet)	O_2 SATURATION (%)
	G.L.	98.0
0	8,000	92.2
5.0	45,000	92.0
12.7	45,000 (down)	59.5
81.2	30,000	95.0
139.6	15,000	97.0

COMMUNICATION:	The pretest mean duration between counts was 1.1 seconds. Following the decompression, the voice was, for the most part, unintelligible with a "muffled" quality. This was apparently caused by the position of the mask on the face. The mean duration between counts increased slightly to 1.5 seconds following the decompression.
PERFORMANCE:	Prior to the decompression, the control column was maintained in the proper position. Following the decompression, the subject failed to reset the column for a period of 20 seconds. This was finally accomplished at the urging of the flight surgeon.
BLOOD CHEMISTRY:	No change in beta/alpha lipoprotein ratio. Questionable changes in LDH. SGOT & SGPT were unchanged.

TEST RUN NO. 8 - FEBRUARY 26, 1963 (PASSENGER)

SUBJECT:	L. K. - Purchasing Agent
AGE:	39
PREVIOUS EXPERIENCE:	Radio operator, B-17, World War II; demand oxygen equipment; considerable skin diving experience
MEDICAL HISTORY:	Several dental fillings past week. Slight obesity
DECOMPRESSION PROFILE:	Initial altitude 8,000 feet - 0 seconds
	Time to reach 30,000 feet - 1.95 seconds
	Decompression time to 44,995 feet - 5 seconds
	Mask (Firewel-passenger) don time from start of decompression - 12 seconds
	Mask don time from signal - 3 seconds
	Dwell time at altitude - 5 seconds
	Descent rate to 15,000 feet (JetStar rate) - 130 seconds
SUBJECT'S EVALUATION:	Felt pressure build-up in chest during decompression, but denies having been unconscious. Was aware of some difficulty in adjusting mask, but felt he could have applied the mask himself if given an additional second or two. Was aware of observer applying mask. Experienced no other adverse reaction.

OBSERVATIONS:

Flight Surgeon: Was alert and swept mask to face rapidly after drop-out. Grabbed harness ring with left hand and twisted harness. At 14 to 16 seconds, eyeballs rolled up, head fell back, hand dropped from the mask. Subject convulsed violently for 3 to 4 seconds. Mask remained on face and secured by observer. Appeared to recover quite rapidly and was completely responsive to questions and commands. Was surprised when informed of his reaction.

Inside Observer: Subject became unconscious approximately 14 to 16 seconds after decompression after having failed twice to place the twisted harness over his head. Recovered quite rapidly and descent was uneventful.

POST-FLIGHT EFFECTS: Medical findings unchanged. Recovered fully without residual effects.

MONITORING INSTRUMENTATION: EEG - Control record revealed good alpha rhythm of 9 cps. per second. Approximately 18 seconds after decompression, high voltage sharp waves, 6 to 7 per second, appeared, lasting until 30 seconds post-decompression. Baseline record returned at 35 seconds. Evidence of severe hypoxia, which triggered convulsive movements.

ECG -

Baseline	- 84/m
Prior to decompression	- 108/m
Decompression	- Not available
Maximum (25 sec.)	- 168/m
Baseline (G.L.)	- 96/m

RESPIRATION

ALTITUDE (Feet)	RESP. RATE (Minutes)	AV. TIDAL VOLUME (Liters)	MINUTE VOLUME (Liters)
8,000	28.7	0.26	7.46
45,000	81.6*	0.49	39.82
30,000	20.8	0.34	7.07
15,000	113.0*	0.01	1.09

*Rates too rapid for accurate measurement.

COMMUNICATION: No differences in pretest and post-test measures were observed.

PERFORMANCE: The most distinct performance decrement was demonstrated by this subject as a result of oxygen deprivation. The mask was shown to be inadequate as the harness became entangled during the subject's attempt to position it on his face. The subject appeared to experience immediate recovery following placement of the mask by the observer.

BLOOD CHEMISTRY: No significant change in beta/alpha lipoprotein. Increase in LDH and questionable increase in SGOT & SGPT.

DISCUSSION AND RECOMMENDATIONS

While the scope of the study did not provide for replication of experimental situations necessary for precise conclusions, a number of interesting problems were identified and valuable information was obtained. In retrospect, it is believed that the precautions instituted by the investigators and the changes in the decompression profiles to more conservative exposures were the major factors in assuring successful completion of the study without serious or permanent injury to any of the test subjects. It is recognized that the precise stress conditions which might exist in an actual aircraft decompression at 45,000 feet cannot be duplicated experimentally in a low pressure chamber, nor can the passenger subjects be randomly selected to provide a more realistic sampling of the traveling public. The results of the study must therefore be interpreted with these limitations in mind.

Of greatest significance was the observation that not a single subject succeeded in correctly executing all of the instructions repeated several times prior to the decompression. It was also apparent that tolerances to hypoxia at 45,000 feet were the same for skilled pilots and naive passengers alike and that tolerance was a function of circulatory mechanics rather than the delivered oxygen pressures and adequacy of dispensing equipment.

The subjects tolerated the decompressions well, despite minor physical disorders such as variable blood pressures, recent dental work, and gastrointestinal upsets. Despite the presence of obesity and advanced age of several subjects and the absence of denitrogenation, none experienced symptoms of aeroembolism. Maximum exposure time above 30,000 feet was 186 seconds for two subjects. For technical reasons, the chamber decompression was started approximately two seconds after the initiation of the electrical timing devices; hence, the mask-donning signal or the mask drop was presented several seconds sooner than originally programmed. Regardless of the mask type, all subjects required 3 to 4 seconds to sweep the mask to the face. Information concerning the initiation of oxygen flow was unreliable, although it is assumed that at the lower altitudes, several additional seconds were required for the oxygen to reach the subject's lungs. When the masks were applied at the higher altitudes, 100% oxygen under pressure should have been immediately available.

The pilots saw the flashing warning light; however, all failed to hear the horn located $1\frac{1}{2}$ feet above ear level. The background noise level in the chamber was increased appreciably during the decompression and subsequent recompression, effectively masking the horn signal. Mild pressure symptoms were experienced in the chest and epigastric areas by two pilots during prolonged exposure at maximum altitude; however, the subjects tolerated pressure breathing unusually well. Subjective awareness of confusion occurred in the two pilots exposed to the 5-second decompressions, and both experienced moderate post-test fatigue. The passenger exposed to the 5-second decompression insisted he was not unconscious and appeared totally incapable of evaluating his true state.

Some degree of pre-decompression excitement was manifest in all subjects. This was verified by a moderate to marked increase in pulse rate during the countdown immediately preceding decompression. The maximum rate increase of 66 per minute was noted in Subject No. 4. The arterial oxygen saturation in Subject No. 5 dropped to a level of 60%; however, he did not appear to be markedly cyanotic or in distress. Electroencephalographic changes, indicative of cerebral hypoxia, were, however, present at the time. In only one test was it necessary for the observer to secure the subject's mask. Difficulty in properly positioning the passenger mask and harness was encountered by all passengers. It is of interest to note that the inside observer and flight surgeon seldom agreed on the speed with which the subjects responded to the mask donning signal. In several subjects, the blood pressures and pulse rates remained slightly elevated after completion of the test. Evidence of aero-emphysema was absent in all cases. One subject completed a comprehensive physical examination several hours after his test with normal findings noted. Subject No. 4 developed a severe barotitis media in one ear, eventually requiring myringotomy. The ear subsequently healed with complete restoration of pretest hearing acuity.

Despite technical difficulties with the instrumentation during the early tests, some significant data were obtained. The EEG reflected the slow wave activity anticipated with cerebral hypoxia. The time of its occurrence varied with the experimental condition, but correlated well with the severe arterial oxygen desaturation noted in the two tests where oximetry was utilized and with the psychomotor impairment in Subjects Nos. 7 and 8. In the two latter exposures, involving similar decompression profiles, the EEG changes persisted from 16 to approximately 40 seconds, despite early re-oxygenation efforts. The EEG records did not identify the location of the abnormal waves. Artifacts caused by head and eyelid movements were common and in many cases obscured the changes occurring during the actual decompression.

The ECG was of greatest value in reflecting changes in heart rates. Rates varied according to the exposure, with maximum rates of 136 to 180 at altitude. In two subjects, premature ventricular extrasystoles were noted, indicating increased myocardial irritability. In Subject No. 7, transient T-wave changes were observed.

Respiratory rate, average tidal volume, and minute volume were determined for six subjects. Change in rates could not be correlated with exposure, since other factors such as excitement and physical stimuli influenced the breathing pattern. Average tidal and minute volumes were more consistently related with exposure at 45,000 feet.

Oximetry was limited to Test Nos. 5 and 7. The location of the earpiece interfered with mask-donning and could not be used in other tests. The low readings obtained in the two cases correlated well with other findings and observations.

Although chamber temperature changes during decompression were marked, the maximum deviation in subject skin temperature was 1.0° F. The slight skin temperature changes were not considered significant or contributory to the study.

The galvanic skin response was difficult to quantitate and interpret. Deflections in the scale cycled randomly and, on occasion, with respiratory movements. Peak changes were noted at maximum altitude in several cases. Otherwise, there was no consistent correlation between the scale deviations and the exposures.

Technical difficulties were encountered in monitoring exhaled carbon dioxide and nitrogen gas concentrations and are described elsewhere in this report.

With respect to communication, the most significant factors associated with the pilot subjects were 1) the poor intelligibility of voice communications;

and 2) the tendency to neglect prior instructions following the decompression. The intelligibility problem was attributable to such factors as oxygen flow noise into the mask, poor mask position on the face, and inability of the subject to speak against increased oxygen pressures. The failure of the subjects to adhere to prior instructions following the decompression was evidenced by variation from the prescribed counting sequence. Speech was, for the most part, unintelligible while pressure breathing above 30,000 feet. The only observable direct effect of the decompression on speech was a noticeable change in voice pitch for one subject. Other effects were not evident, possibly as a result of inadequate response of the microphones with the low ambient pressures encountered after the onset of decompression. There was also an observable decrease in the intervals between the spoken numbers following decompression.

In Test No. 2, the pilot released the control column upon hearing the flight surgeon's instruction to decompress the chamber. Pilot Subject Nos. 3 and 7 both encountered difficulty in positioning the control column after decompression and did so only after numerous commands. The passengers experienced difficulty in positioning and properly securing the mask despite prior instructions and demonstrations.

The most dramatic tests, Nos. 7 and 8, involved pilot and passenger exposures of almost identical degree. Both were exposed to altitudes in excess of 30,000 feet for 10 seconds prior to mask-donning. The pilot was able to secure his mask, whereas the passenger, while able to sweep the mask to his face, was unable to secure the harness. Both subjects became unconscious between 14 to 16 seconds after start of decompression, with EEG changes indicative of severe cerebral hypoxia. Both recovered quite rapidly, although the pilot apparently experienced a greater degree of confusion. The passenger denied having lost consciousness and had more difficulty in evaluating his true condition. It is apparent that an oxygen mask must be applied and the subject breathing oxygen in less than seven seconds at 45,000 feet in order to avoid transient unconsciousness. Since all pilots required at least three seconds to apply easily-reached, quick-donning type masks, it is questionable as to whether a pilot rapidly decompressed to 45,000 feet in an actual aircraft emergency could successfully don his mask in sufficient time to avoid some degree of unconsciousness and confusion.

Blood enzyme studies were essentially noncontributory, with questionable changes in the more severe 5-second decompressions in Tests 7 and 8. It may be assumed that decompressions and superimposed hypoxia of a magnitude experienced in this study do not result in significant cellular damage. While it was not the intent of the study to evaluate oxygen mask and dispensing systems, some observations are worthy of note. A number of problems were encountered with the use of the various quick-donning crew masks. The Sierra mask was preadjusted to fit two pilots and required little post-decompression readjustment. In one case, the mask leaked excessively at the upper nasal area. There were no unusual reactions in the second case. The Aro-Firewel crew mask was used by one pilot. Excessive leakage resulted while breathing pressures of 10 inches of water due to loose preflight fitting requiring the pilot to hold the mask tightly against his face.

The Puritan sweep-on mask was used in the final pilot test. The subject was able, without difficulty, to reach the mask located above his head; however, the rear plastic support bar, which normally fits near the nape of the neck, was positioned high above the occipital area. This resulted in a distortion of the mask; however, a fairly adequate seal was obtained. Under actual flight conditions, movements of the head in the cockpit could easily have resulted in mask loss or displacement.

A number of deficiencies were noted in the Firewel passenger mask. Two of the four subjects positioned the mask as instructed and pulled the harness up and over the occipit of the head until the handle was at the nape of the neck. The lateral straps, however, were positioned above the ears rather than below. Normally, the straps should follow the lower jaw line and continue under the ears. The poor positioning resulted in an upward displacement of the mask assembly, requiring the passengers to hold the mask down and to the face in order to obtain a proper fit. One subject positioned the mask over the mouth, but below the nose, and failed to correct the placement until assisted by the observer. Subject No. 8, who was exposed to the 5-second decompression, was unable to pull the harness over his head. Upon reviewing the films of the test, it was evident that the mask dropped promptly as scheduled, but did not rotate fully toward the subject. In snatching at the mask with his right hand, the subject disconnected the harness from the storage clip and rotated the assembly 180 degrees. It would have been impossible for him to have properly secured the harness without first correcting the twisted straps. The subject lost consciousness at 14 seconds; however, the mask remained positioned on his face. The instructor quickly secured the mask and recovery was rapidly effected. The fourth passenger was fitted with a mask at 8,000 feet immediately prior to the decompression. There were no apparent mask difficulties during this test. Upon removal of the mask, areas of redness and swelling were noted at the points of mask contact.

As an added safety precaution, the inside observers wore Canadian waistcoats with A-13A pressure demand masks. It was believed that equalization of the transthoracic pressure in subjects repeatedly exposed to high altitude decompressions would minimize the risk of lung injury. This would assure maximum performance capability for the instructors should emergency services to the subject be required. Previous experience with various types of pressure garments and vests indicated that decompressions could be tolerated to 50,000 feet with the waistcoat, if used in conjunction with an anti-"G" suit. There was some question as to the need for the anti-"G" suit in decompressions up to 45,000 feet; consequently, a trial decompression was performed utilizing the waistcoat and mask only. The decompression was extremely well-tolerated by the subject, despite a pressure of 17 inches of water delivered to the waistcoat and mask by an F-24 (Firewel) suit regulator. There was no manifest stagnation of blood in the lower extremities. This degree of pressure provided a 40,000 foot altitude equivalent.

It would also have been desirable to use a head-encasing helmet, such as the MA-3, to prevent mask separation at the higher pressures. It was decided, however, that the benefits derived by the use of a helmet would be more than offset by the psychological effect on the test subject.

The observers' evaluation of their equipment was entirely favorable. They experienced no major difficulties other than excessive leakage of oxygen from the nasal area during the more rapid decompressions. There was no objective evidence of performance interference or degradation in either of the two observers.

The study reveals the critical nature of rapid decompressions at 45,000 feet and the extremely small margin of safety afforded pilots in avoiding loss of consciousness if oxygen masks are not worn prior to the decompression. It may be anticipated that similar reactions will occur at altitudes as low as

40,000 feet and that a considerable margin of safety cannot be readily assured for altitudes as low as 35,000 feet. It is also apparent that despite the controlled nature of the study, repetitious instructions to both skilled and naive subjects, and minimal demands for coordinated action, the physical aspects of the decompression event and the excitement associated with it precluded a completely successful response from a single subject. Additional studies are recommended for the solution of a number of problems evolved during the program:

1. <u>Pilot Communication</u>

   Intelligibility of pilot communications using the oxygen mask microphone was extremely poor. While this was partially a function of mask positioning, one of the major decrements to intelligibility was oxygen flow noise. In considering this problem, it is possible that a spectral analysis of the oxygen flow noise may show a narrow band noise relative to the speech signal. If this assumption is correct, a narrow band filter could effectively remove this interference with little effect on the voice signal. It is recommended that this and the entire problem of communication above 40,000 feet be studied in greater detail. In addition, none of the pilots heard the warning horn. In this study, the presence of other physical phenomena such as fogging and noise would have alerted the pilot to the emergency. In slower decompressions, these phenomena may not necessarily be prominent. Studies should be conducted to determine the adequacy of warning horns.

   Studies should also be conducted to determine the most efficient earphones to be used in conjunction with the quick-donning mask microphones.

2. <u>Pilot Performance</u>

   A controlled evaluation of pilot performance during decompression is recommended. The test situation should include simulation of standard procedures during decompression. Activities such as mask-donning, aircraft control, and communication should be evaluated. This would involve an extension of the testing performed in this study.

3. Visual Correlates of Decompression

Visual functions such as depth perception, estimation of closing times, perception of instruments, and vigilence should be evaluated during decompression and descent. Because of the fogging, the visual warning light was not easily discernible.

4. Equipment Evaluation

It is apparent that additional studies should be performed to determine the most effective type of protective equipment to be worn by pilots during flights above 45,000 to 50,000 feet. This research should have as its major objective the evolution of design criteria for the development of simple, lightweight equipment which will assure both survivability and maximum performance capability for pilots and other vital crewmen during decompression above these altitudes. This is necessary to assure rapid descent to an altitude compatible with safety for passengers who may or may not be able to apply their oxygen masks. The inadequacy of the passenger mask was dramatically demonstrated. Additional information is needed to determine passenger capabilities to don masks under stressful conditions. The need for further development in passenger mask design is obvious.

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APPENDICES

BIOINSTRUMENTATION

ELECTRODE APPLICATION

1. Lead Cup Electrodes for EEG and ECG

Areas of application were scrubbed vigorously with acetone-saturated cotton balls to remove oil, dandruff, and epidermis. Hair on the head was parted over each area to reduce the number of hairs which would be caught under the electrodes and in the surrounding collodion.

Clean, dry electrodes were held firmly, but gently, in place with a metal rod as the collodion was applied. Cotton-tipped applicator sticks dipped in collodion were used. During and for a few minutes after the application of collodion, the holding rod was rotated to prevent it from becoming adherent to the electrode. A portable hair dryer held a few inches from the electrode helped speed the drying of the collodion.

A blunt, 19-gauge needle was used to scrape the scalp prior to filling the cup of the electrode with electrode paste. A 2 centimeter syringe, attached to the above-noted needle, provided more than enough electrode paste for all electrodes.

Electrode removal was accomplished with ease by sponging the collodion with acetone-saturated cotton balls. Acetone was then used to remove remaining particles of collodion from the hair and from the electrode. Warm water was used to remove electrode paste, and by storing the cleaned electrodes in distilled water, residual paste was kept from drying. If electrode paste is allowed to dry, it must be sanded off the electrode before reuse.

2. Electroencephalogram Electrodes

Several configurations of electrode placement were employed in the course of the study. Among them, placement of electrodes on the forehead and the temporal areas was tried. Placement which proved most effective with a minimum of interference from muscular activity included:

a. Common electrode placement at the vertex
b. No. 1 pickup electrode placed in the pariental area, midway on a line between the vertex and the helix of the ear on the major side of the brain
c. No. 2 pickup electrode placed over the occiput on the major side.

Cup electrodes were utilized entirely with the exception of a few ground level trials and one decompression test with needle electrodes. It was extremely difficult to secure the needle electrodes in a manner which would prevent them from being disturbed or dislodged when masks were donned.

3. Electrocardiogram Electrodes

Two modes of gathering electrocardiographic data were tried. One included electrodes placed bilaterally at the intersection of lines extending transversely from the nipples and longitudinally at the anterior axillary line, with grounding at the left ankle. Although this placement of electrodes provided readable ECG tracings, the baseline was inclined to wander with body movement.

Electrode placement which proved most effective and was utilized in all of the decompression tests included:

a. Common ground electrode attached over the vertebral column at the level of T-8

b. One electrode placed over the sternum at the level of the manubrio-sternal junction

c. One electrode placed over the vertebral column at the level of the lumbosacral junction.

The above placement gave tracings closely paralleling Standard Lead I. Cup electrodes were employed throughout, with the exception of the first test and some preliminary ground level testing with wire mesh electrodes.

4. Body Temperature Electrodes

A 3/8 inch square of copper foil attached in the axilla was used to measure skin temperature. The area for attachment was first cleansed with an alcohol sponge. Hair was either trimmed or shaved for comfort in removal of tape. Tincture of Benzoin was then applied to the area which would be covered by adhesive tape.

The electrode was placed against the dry skin, followed by foam rubber insulation material and two or three 4 inch strips of adhesive tape to assure adequate positioning.

5. Impedance Pneumograph Electrode

Ventilation measurements were obtained with two silver-plate electrodes placed dorsi-laterally at approximately the level of the seventh rib. The skin was cleansed with alcohol and Tincture of Benzoin applied to areas which would be covered with tape.

The electrodes were then generously coated with electrode paste. The electrodes were held firmly against the skin and rocked back and forth to assure contact. Two 4 inch strips of 1 inch adhesive secured the electrodes.

6. Galvanic Skin Response Electrodes

Initially, electrodes were attached to the plantar surfaces of both feet. These were later modified and a split lead electrode was attached to one foot. In a further attempt to reduce artifacts introduced by foot movements, a 1 inch diameter split lead electrode was applied to one heel. Aluminum foil was used during early ground level tests and some of the early decompressions. Lead foil was employed during later tests and proved to be more satisfactory. Method of attachment was:

a. The area of attachment of the electrode was vigorously scrubbed with alcohol and thoroughly dried

b. The dry electrode was then secured in place with an elastic bandage.

7. Measuring Resistance of Electrodes

Following the application and filling of cup electrodes, the electrical resistance between electrodes was measured to determine whether good contact had been made. High resistance values are one indication of poor electrode contact. When it occurs, the offending electrode may be identified by a process of elimination and checked for poor contact. Improved contact may be achieved by scraping of the skin and adding more electrode paste. At times, it was found necessary to remove and reapply an electrode, following the above procedure.

INSTRUMENTATION SUMMARY

The integrated instrumentation system measured the following parameters: 1) ECG; 2) EEG; 3) psychogalvanic skin response; 4) respiration for rate and volume; 5) respiratory gas for CO_2 and N_2 content; 6) blood oxygen saturation; 7) subject body temperature; 8) oxygen flow rate; 9) test chamber air temperature; 10) oximeter earpiece temperature; 11) oxygen supply temperature; 12) test chamber air pressure; and 13) oxygen supply bottle pressure.

Items 1 through 6, 8 and 12 were recorded on the multi-channel Minneapolis-Honeywell Visicorder. Items 1 and 2 were also recorded on a Mini-polygraph at the medical observation post. Items 7, 9, 10 and 11 were recorded on a continuous write-out, Brown Instrument Division, 2-pen strip chart Electronik recorder. The subject's temperature was recorded continually. Any one of the other three temperatures could be selected with a manual switch. Item 13 was noted on a pressure gauge.

1. Electrocardiography (ECG)

The electrocardiograph recording system was quite similar to that of the EEG system. Standard clinical leads could not be used, as the subjects were neither prone nor resting. The electrode placement followed that developed in WADC TR 58-453, "A System for Monitoring the Electrocardiogram During Body Movement."

2. Electroencephalography (EEG)

The brain bioelectric signals picked up by the electrodes attached to the scalp were transmitted through a 25-foot long shielded cable having three number 14 wires to a G.M.E. Mini-polygraph recorder at the medical observer's station, where the attending doctor or doctors could monitor the continuous recording. The signal was taken from the oscilloscope output jack, fed into a preamplifier, and then into the low impedance, multi-channel Visicorder.

Initially, in setting up the instrumentation, it was planned to use a G.M.E. portable Cardio-Encephalograph. The mass of the pen write-out system provides enough damping to give a good written record, but the electric signal taken from the instrument to be fed into the Visicorder had so much hum that it would not give a clean record. After several unsuccessful attempts to filter the signal, the change was made to the Mini-polygraph.

Lead-solder cup electrodes were used in the first test runs, but various artifacts gave an unsatisfactory recording. Needle electrodes were recommended. These were obtained and used in the second test run, but in the run, an electrode twice slipped out of the scalp during the subject's body movements and thus gave another unsatisfactory record. For the third test run, the needle electrodes were cemented in place with collodion. The results were improved, but still not entirely satisfactory.

Because there was to be a two-week delay in the test program, an investigation was initiated into electroencephalographic techniques. A review of the electrical resistance values of the electrodes used in the first three tests showed high, scattered resistance values. Our electrode attachment techniques were re-evaluated and revisions were made. The lead cups properly applied were found to give good results, with resistance values closely grouped and under 5,000 ohms. The needle electrodes gave closely-grouped results, but the resistance values were always between 33,000 and 35,000 ohms. The lead cup electrodes were used in the last five tests with better results. The resistance values at the time of installing the electrodes were grouped within a variation of ± 500 ohms. The groups' resistances were 3,000 ± 1,000 ohms.

3. Psychogalvanic Skin Response (GSR)

The psychogalvanic skin response is an indicator of autonomic activity. The GSR can furnish dependable information about the level of sympathetic activity provided the various factors outside the nervous system which affect them are adequately controlled. These factors include electrode size and composition, skin temperature, contact medium, electrode composition, and electronic circuitry, as well as a miscellaneous group of variables. It is thus difficult to evaluate a group of subjects.

The battery-operated GSR instrument supplied a constant voltage to the electrode whose signal was then fed to a preamplifier and to the Visicorder. Because the subject's hands had to be free, the electrodes were placed on his feet. The best arrangement was a split-lead electrode on one heel. The electrode was 1.50 inches in diameter with an 0.25 inch gap between the electrode halves. When a plantar electrode was used on each foot, it was found that it set interference in the ECG signal. Foot movement also could cause a muscle artifact in the GSR signal.

4. Respiration

The respiration rate and volume were determined with an impedance pneumograph. After the instrumented test subject was seated in the altitude chamber, the impedance pneumograph was calibrated against a spirometer. The subject breathed normally into the spirometer until his pattern stabilized, at which time the Visicorder was turned on and the pattern recorded. This was repeated with the subject breathing deeply. Thus from the known values of the spirometer chart, the impedance pneumogram record values could be determined. These findings are summarized in Table 1.

5. Respiratory Gas Analysis

The gas sample was pumped through an 0.125 inch O.D. tube to the carbon dioxide and nitrogen sensor units and then back into the altitude chamber. The carbon dioxide sensor required a flow of 500 ml/minute and the nitrogen sensor 5 ml/minute. The vacuum pump for the nitrogen ionization sensor had sufficient capacity to operate against the negative pressure head at altitude, but the carbon dioxide pump did not, even when various pumping schemes were used. Numerous repairs to the nitrogen analyzer were not lasting, so the unit was returned to the manufacturer for repairs and the local vendor representative's demonstration model was used in part of the test program. The over-all gas analysis results were not entirely satisfactory. An electric signal taken from each analyzer was put into the Visicorder for recording.

6. Blood Oxygen Saturation

An ear oximeter was used to determine the blood oxygen saturation. The earpiece detector assembly is quite sensitive to movement on the ear lobe, so it was used on only two subjects.

The galvanometer control box had been previously modified so that the output signal could be amplified and recorded as well as read remotely. The recorder previously used was of high impedance, so difficulty was encountered using the low impedance Visicorder. The modifications were changed to be compatible with the Visicorder. The remote readout meter was also changed to be compatible with the new system.

7. Body Temperature

The body temperature was measured with a copper-constantan thermocouple topped in the axilla. The thermocouple junction was covered with thermal insulator for more accurate readings. The electrical signal was read out continually on a Brown Instrument Division pen recorder.

8. Oxygen Flow Rate

The oxygen flow rate was measured with a certified, calibrated orifice flow meter. The upstream and downstream pressures were sensed by a differential pressure transducer. The output signal was amplified and fed to the Visicorder.

9. Test Chamber Air Temperature

The chamber air temperature was sensed with a copper-constantan thermocouple and could be recorded on a Brown Recorder. This was one of three temperatures that could be selected with a manual switch for recording.

10. Oximeter Earpiece Temperature

Previous tests with the ear oximeter have shown the necessity of knowing the stabilized temperature of the earpiece for more accurate determinations of the blood oxygen saturation.

11. Oxygen Temperature

The oxygen temperature at the flow meter inlet was measured with a copper-constantan thermocouple, which was read out on the Brown Temperature Recorder. This temperature was selected with the manual switch.

12. Chamber Air Pressure

A pressure transducer was used to sense the pressure changes in the altitude chamber. The electrical output signal was amplified and fed to the Visicorder for recording.

13. Mask Oxygen Bottle Supply Pressure

This pressure was indicated on a gauge and was recorded before and after each test. The bottle pressure was reduced with a regulator to 90 p.s.i.g. for the supply line working pressure.

In summary, the following is a list of the recording and indicating instruments used in the test program:

1. 24-channel Visicorder, Model 1108, manufactured by the Minneapolis-Honeywell Regulator Company (the primary recording instrument)
2. 2-pen, continuous write-out, strip chart, Electronik Recorder, manufactured by the Brown Instrument Company, Division of the Minneapolis-Honeywell Regulator Company
3. Gilson Medical Electronics Mini-polygraph, Model M5P
4. Beckman/Spinco Medical Gas Analyzer, Model LB1
5. Waters Corporation Nitrogen Gas Analyzer, Model A-7
6. Waters Corporation Ear Oximeter, Model X60A
7. Biophysical Research Associates Galvanic Skin Response Meter
8. A specially-modified, battery-operated, E. & M. Instrument Company Impedance Pneumograph.

WARNING LIGHT, HORN, AND SEATS

Warning lights of two different voltages and power were used. In Test No. 1, an amber lamp, 6 volts and 6 candle power, was installed 8 feet in front of the subject and approximately 1 foot above eye level. The lamp flashed at 1 second intervals. Despite a lamp face area of $3\frac{1}{2}$ inch width, the subject had difficulty seeing the light through the fog. For all subsequent tests, an amber flashing lamp of 24 volt and 24 candle power was used and was positioned $4\frac{1}{2}$ feet in front and 1 foot above the head. This light was discernible to the subjects.

The warning horn used during the first test was placed at approximately the same distance from the subject as the light. The horn, operated by a 24 volt source, had an intermittency of 1 second and was sequenced with the light. The horn signal was masked by chamber noise and was not heard by the subjects.

In subsequent tests, the horn, of a type similar to that currently used in the Electra aircraft, was moved to a position 1 foot above and 2 feet from the left shoulder of the subject. Despite this relocation, the horn was still inaudible to the subjects and frequently to the observers.

Two types of seats were available. For the passenger tests, a standard double Electra reclining seat was used with the subject restrained by a lap belt. For the pilot tests, a Navy YP3A crew seat with standard headrest and retractable arm rests was utilized. A single modification was made in the seat. The subject's body was supported by a fish net type of material used in the seat back and cushion areas, providing a more comfortable body support surface. The pilots were strapped into the seat with standard lap belts and shoulder harnesses.

MEDICAL FORMS AND SUPPLIES

Flight Surgeon's Check List

I. DAY PRIOR TO TEST
   A. Contact subject
   B. Check medical records
   C. Alert ambulance and driver
   D. Contact Straus Laboratory
   E. Discuss projected chamber profile (chamber)
   F. Discuss emergency procedure (chamber)

II. TEST DAY
   A. Examining Room
      1. Change to flight suit
      2. Medical inspection
      3. Initiation of work sheet
      4. Application of electrodes
         a. EEG
         b. ECG
         c. Temperature
         d. Pneumograph
         e. GSR
      5. Apply nasal tube
      6. Check resistance with ohmmeter
      7. Brief subject
      8. 20 cc. blood specimen taken and prepared
   B. In Chamber
      1. Apply oximeter
      2. Calibrate
         a. Oximeter
         b. Pneumograph
         c. Gas flowmeters
      3. Apply restraining harness
      4. Coordination of following:
         a. Communication engineer
         b. Photographer

c. Inside observer

d. Lock observer

e. Chamber operator

f. Standby nurse

g. Instrumentation engineer

5. Instrumentation checkout

a. Flight Surgeon's position

(1) EEG

(2) ECG

(3) Oximeter

(4) Manometer

(5) Clock

b. Other instrumentation

(1) EEG

(2) ECG

(3) Temperature

(4) GSR

(5) Pneumograph

(6) CO_2

(7) N_2

(8) Oximeter

(9) Chamber pressure

6. Communication checkout

a. Test subject

b. Inside observer

c. Lock observer

d. Main chamber operator

e. Lock operator

f. Instrumentation engineer

g. Communication engineer

h. Photographer

7. Brief subject

III. IN FLIGHT PROCEDURES

A. Decompression of C-3 to 5,000 feet at 2,000 feet per minute

B. Recompression of C-3 to 3,000 feet at 2,000 feet per minute for ear check

Flight Surgeon's Check List

C. Decompression of C-2 and C-3 to 8,000 feet at 2,000 feet per minute

D. Final instrumentation checkout

E. Final communications checkout

F. Final instructions to subject

G. Lights and camera on

H. Commence countdown

I. Decompression of C-3 to 45,000 feet at predetermined rate and recompression profile

J. Decompression of C-2 to 15,000 feet as rapidly as possible

K. Stabilize C-3 at 15,000 feet for ear check

L. Descent to ground level, C-2 and C-3, at rates specified by flight surgeon

M. Remove restrictive attachments

N. Subject returns to examining room

IV. POST-FLIGHT PROCEDURES

A. Examining Room

1. Obtain 20 cc. blood specimen and prepare
2. Physical inspection and interrogation
3. Remove all electrodes
4. Completion of work sheet
5. Release of ambulance
6. Blood specimens to Straus Laboratory
7. Instructions and flight surgeon's phone number to subject

V. DAY FOLLOWING DECOMPRESSION

A. Final interview (phone)

B. Chest X-ray and examination, if indicated

C. Final completion of work sheet.

Medical Work Sheet

NAME: ______________________ CLK# ______________________ AGE: ________

DEPT: ______________ EXT: ________ JOB CLASSIFICATION: ______________

DATE OF TEST: ______________________ CODE NO: ______________

PRE-TEST

SUBJECTIVE COMPLAINTS, IF ANY: ______________________

PHYSICAL FINDINGS: ______________________

BLOOD SPECIMEN NO. 1 (TIME): ______________________

REACTIONS OBSERVED DURING TEST: ______________________

POST-TEST

BLOOD SPECIMEN NO. 2 (TIME): ______________________

SUBJECTIVE REACTIONS: ______________________

PHYSICAL FINDINGS: ______________________

FOLLOW-UP, IF INDICATED: ______________________

____

INVESTIGATOR

Emergency Drug List

	QUANTITY
Caffeine with Sodium Benzoate, 2 cc. ampules, 0.5 gm ($7\frac{1}{2}$ grs) Lilly, Intramuscular	2
Adrenalin chloride solution (1:1000 Adrenalin) 1 cc. ampule Parke-Davis, I.M., Hypo., I.V., I Cardiac.	2
Metrazol, 0.1 gm., 1 cc. ampule Bilhuber-Knoll	2
Coramine, 25% aq. Sol., 1.5 cc. Ciba	2
Atropine, gr. 1/150, tabs.	20
Aminophyllin, 500 mg. (gr. $7\frac{1}{2}$)	1
Aminophyllin, 250 mg. (gr. 3-3/4)	3
Vasoxyl Kit 5% Dextrose in water, 250 cc., Adm. set. 20g x $1\frac{1}{2}$" needle, Vasoxyl, 20 mg., 1 cc. ampule (2)	1
Expandex Kit	1
Plasma, Emergency transfusion set	1
Neosynephrine Pediatric Spray	qs
Marezine, 50 mg. tabs.	qs
Sudafed, 60 mg. tabs.	qs
Benzedrex inhalers	qs
Aromatic Ammonia ampules	qs
Tuberculin syringe (disposable) needle 27g x 1/2"	6
Syringe (disposable) $2\frac{1}{2}$ cc., Needle 25x 5/8"	6
Glass syringe, 2 cc.	2
Glass syringe, 10 cc.	2
Glass syringe, 20 cc.	1
Needles:	
25g x 5/8"	1
23g x 2"	1
20g x $1\frac{1}{2}$"	4
20g x $3\frac{1}{4}$"	2

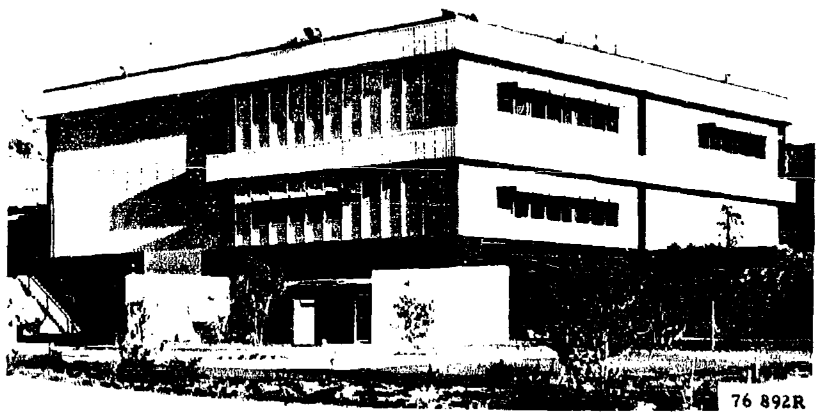

Figure 1 Altitude and Space Environment Facility
Rye Canyon

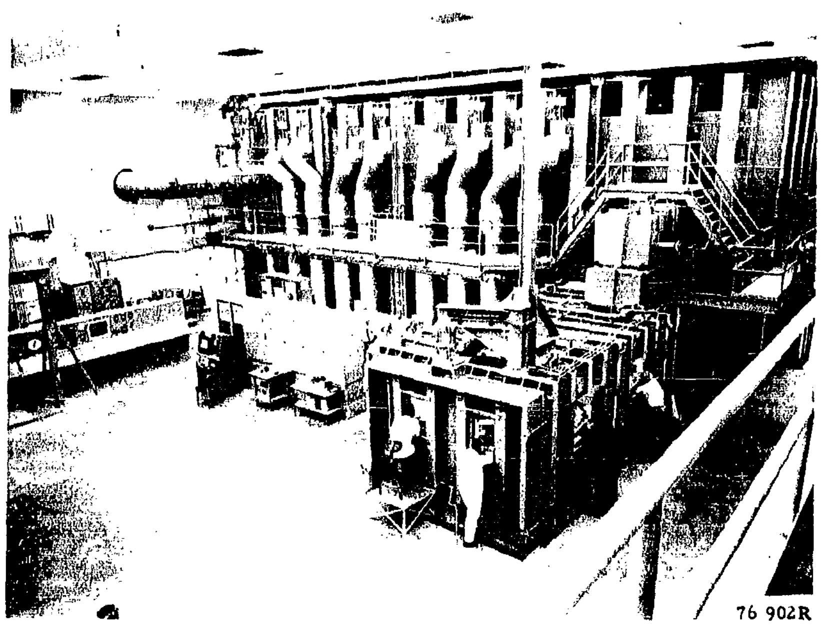

Figure 2 Personnel Test Chamber
C-3

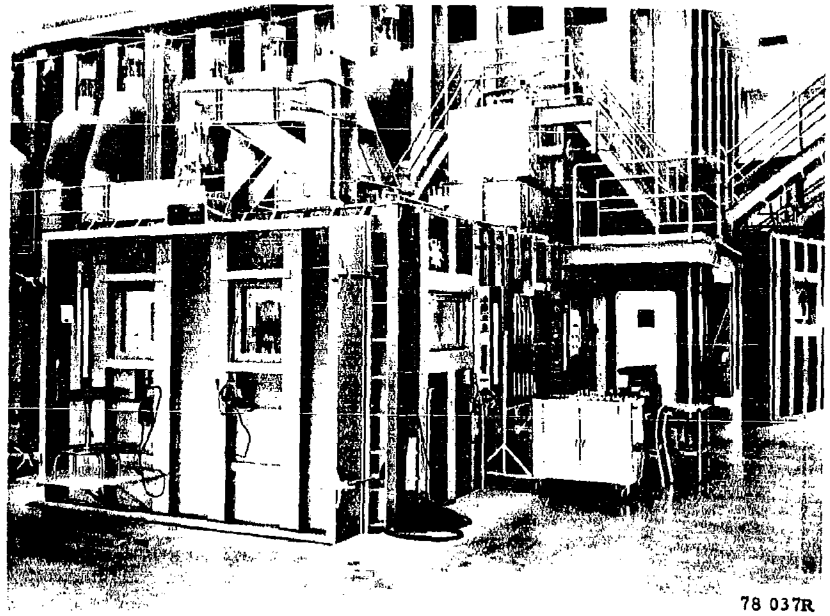

Figure 3 Removable Door
Personnel Test Chamber

Figure 4 Interior
Personnel Test Chamber

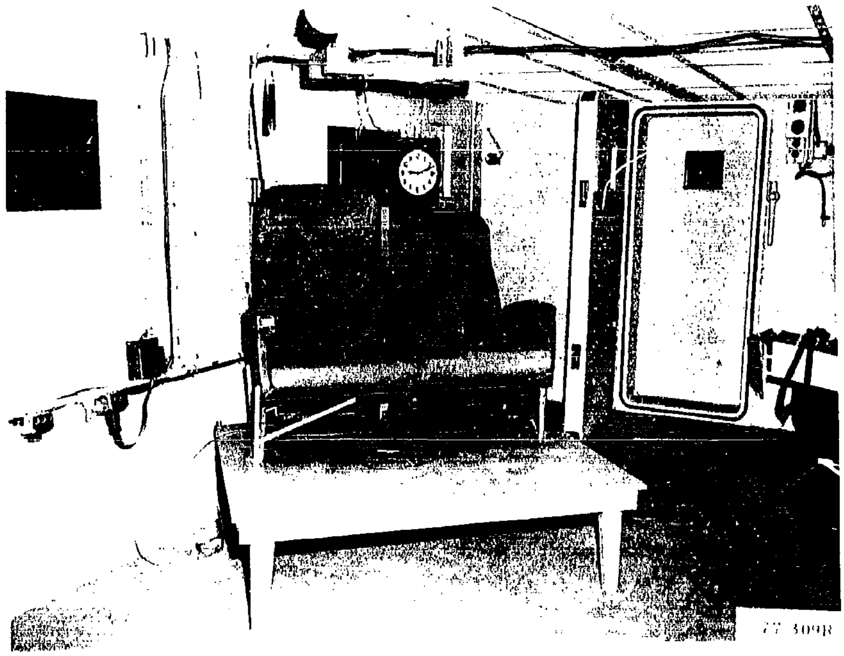

Figure 5 Passenger Seats
Personnel Test Chamber

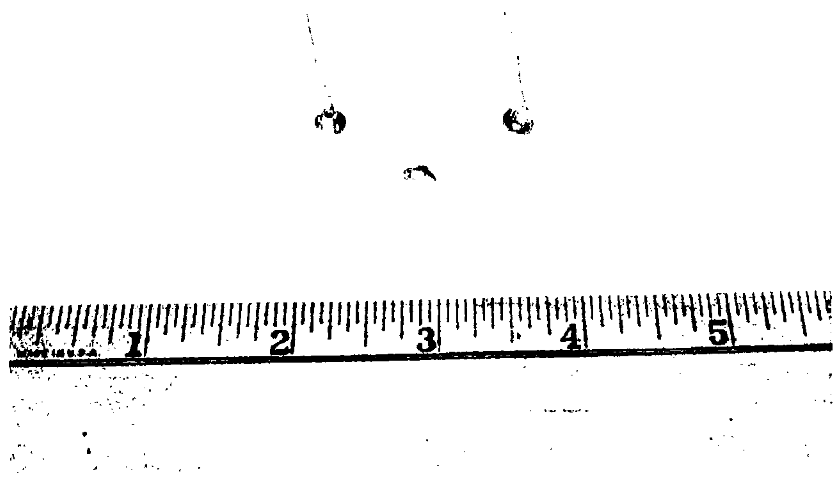

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Figure 6 Electroencephalographic and
Electrocardiographic Electrodes

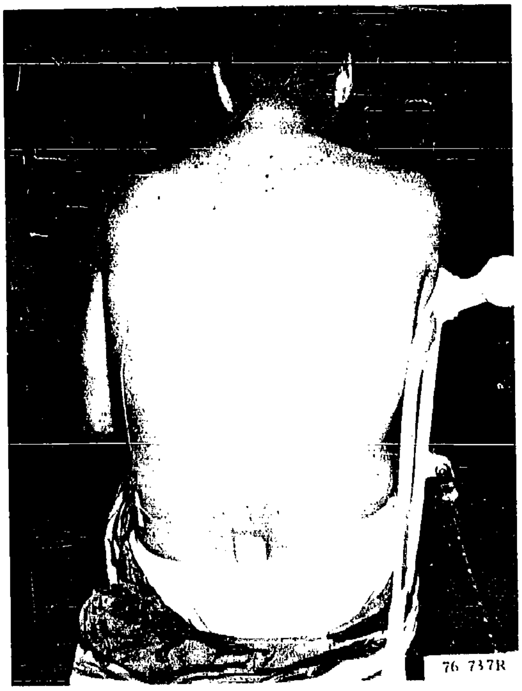


Figure 7 Electrocardiographic Electrodes

Figure 8 Electroencephalographic Electrode Application

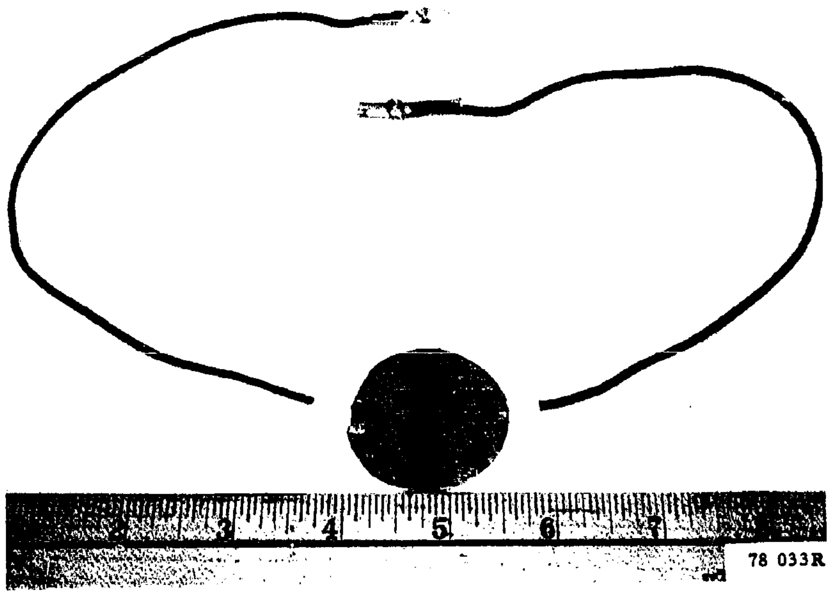


Figure 9 GSR Electrodes

Figure 10 GSR Electrode Application

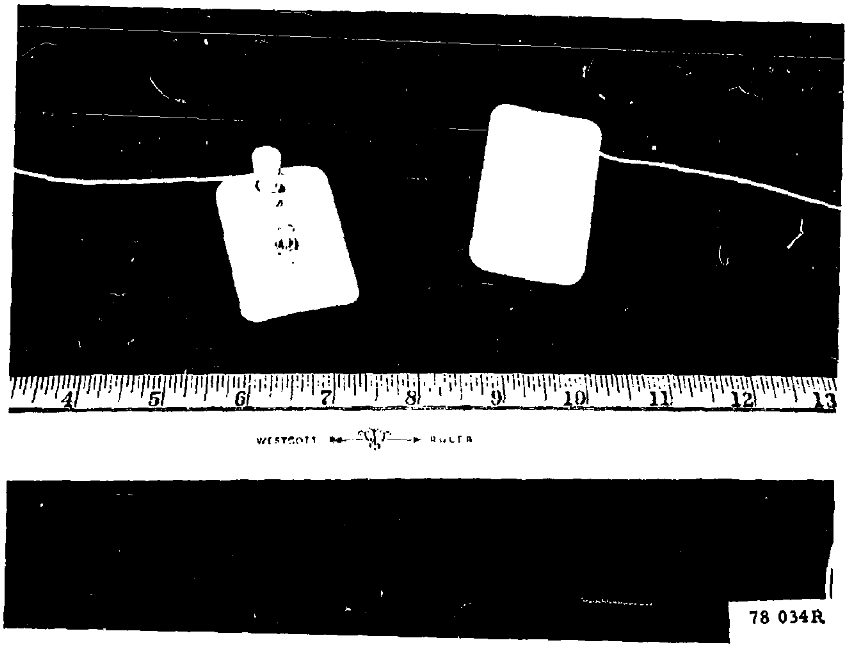
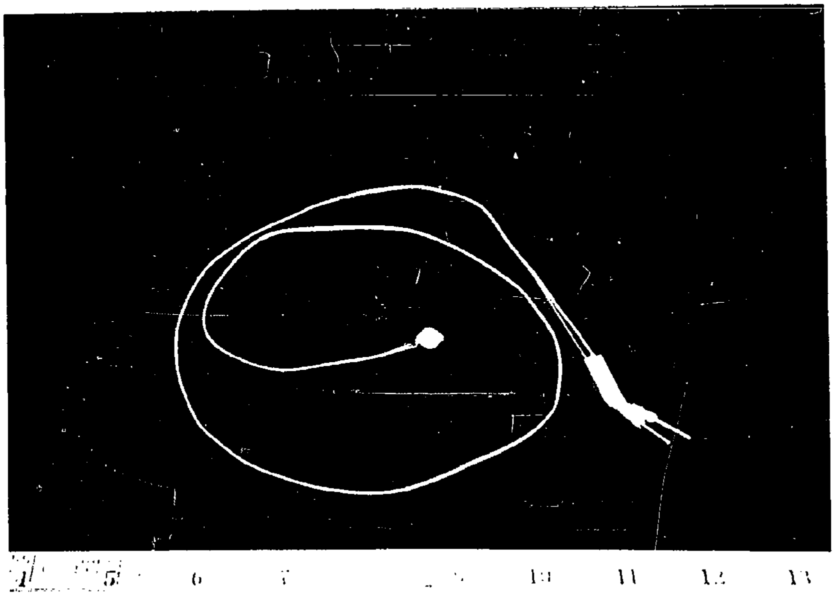


Figure 11 Impedance Pneumograph Electrodes

Figure 12 Position of Electrode Impedance Pneumograph

Figure 13 Nasal Tube in Position Beneath Nostril

Figure 14 Thermocouple and Electrode Impedance Pneumograph



78 035R

Figure 15 Thermocouple
Skin Temperature

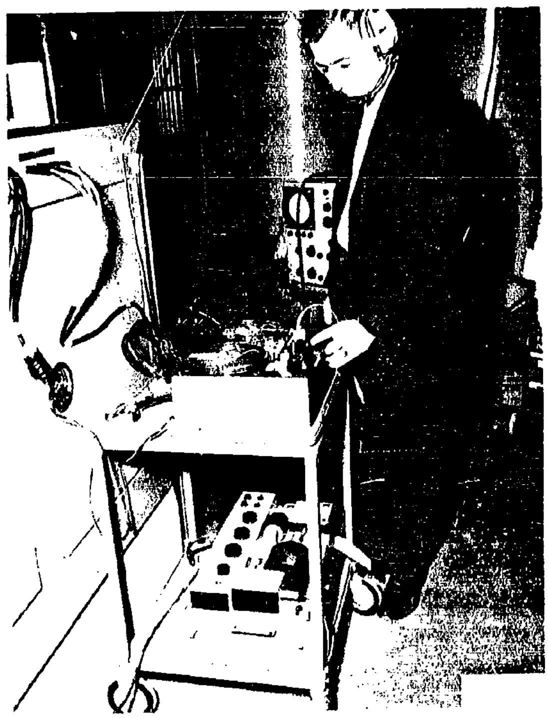


Figure 16 Tape Recording of
Verbalizations

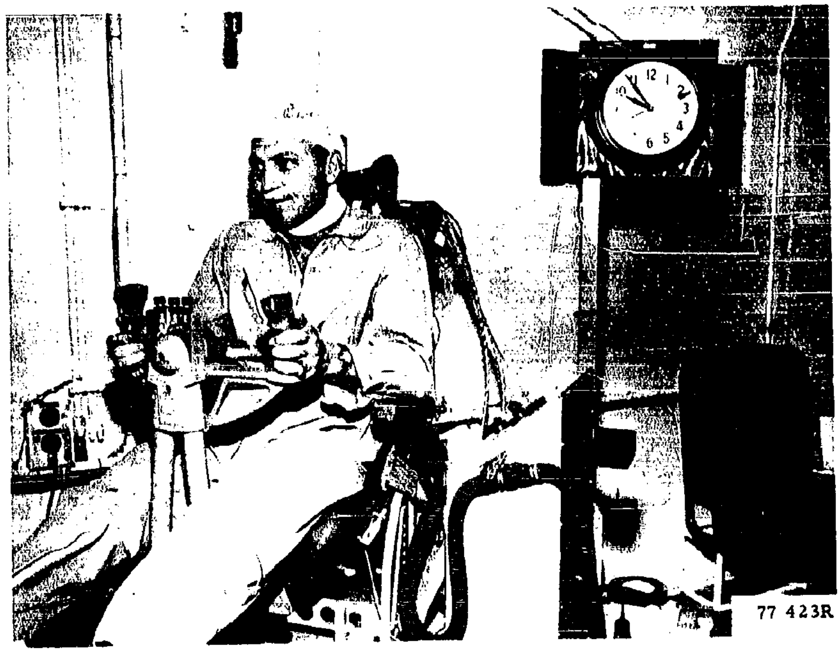


Figure 17 Control Column in Position

Figure 18 Pilot Reaching for Mask

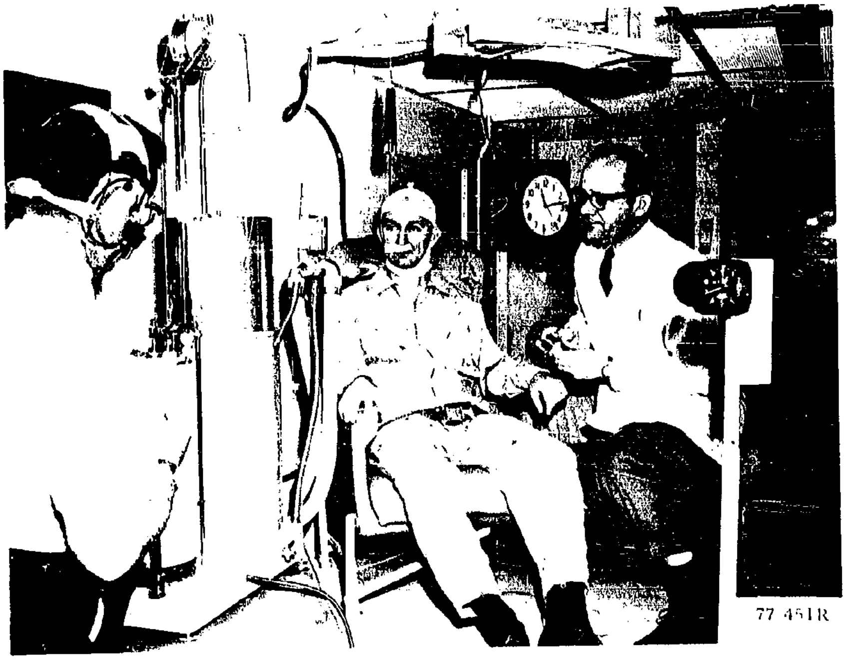


Figure 19 Overhead Mask Drop Box

Figure 20 Passenger Mask in Proper Position

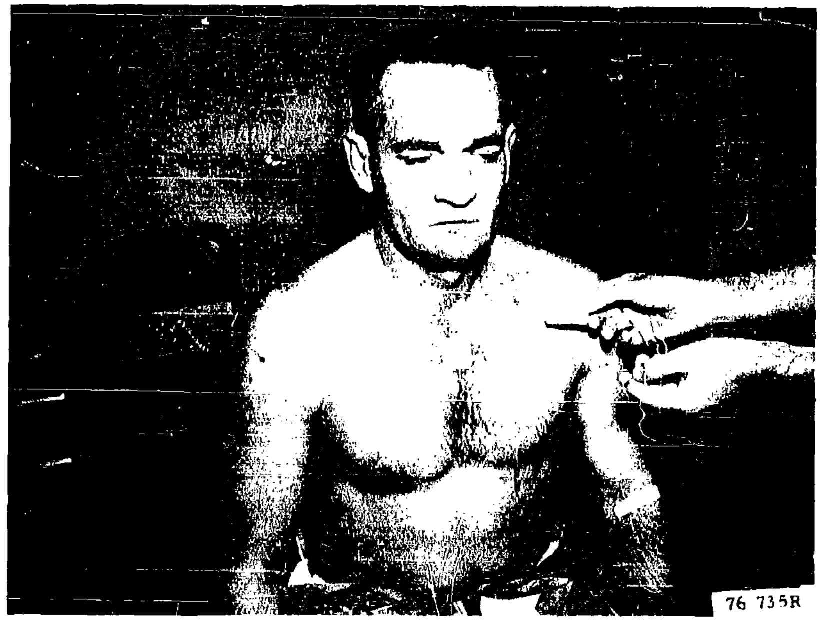


Figure 21 Test Subject No. 1
(Pilot)

Figure 22 Test Subject No. 2
(Pilot)

Figure 23 Test Subject No. 3
(Pilot)

Figure 24 Test Subject No. 4
(Passenger)

Figure 25 Test Subject No. 5 (Passenger)

Figure 26 Test Subject No. 6 (Passenger)

Figure 27 Test Subject No. 7
(Pilot)

Figure 28 Test Subject No. 8
(Passenger)

Figure 29 Preflight Examination
Blood Pressure

Figure 30 Preflight Examination
Tympanic Membranes

Figure 31 Preflight Examination
Throat

Figure 32 Preflight Examination
Heart

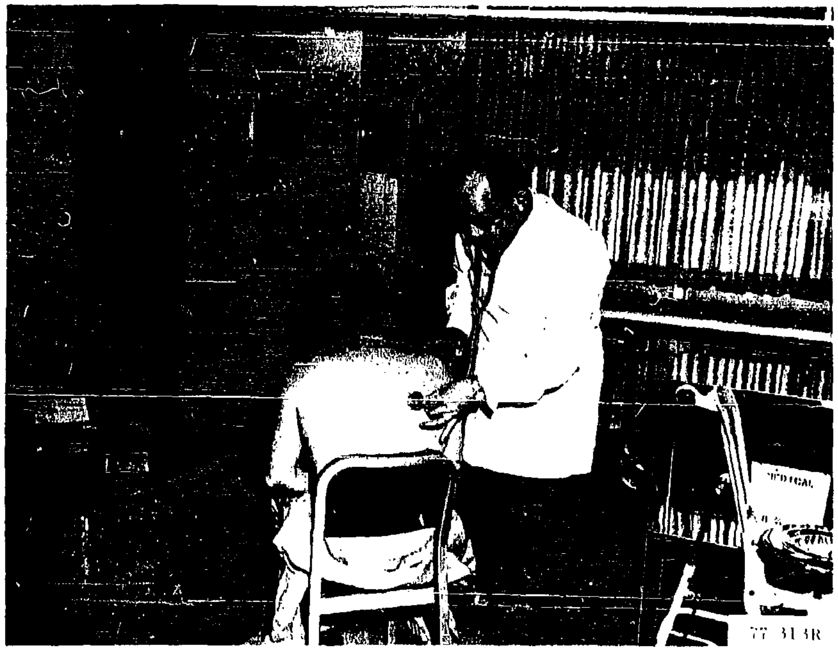
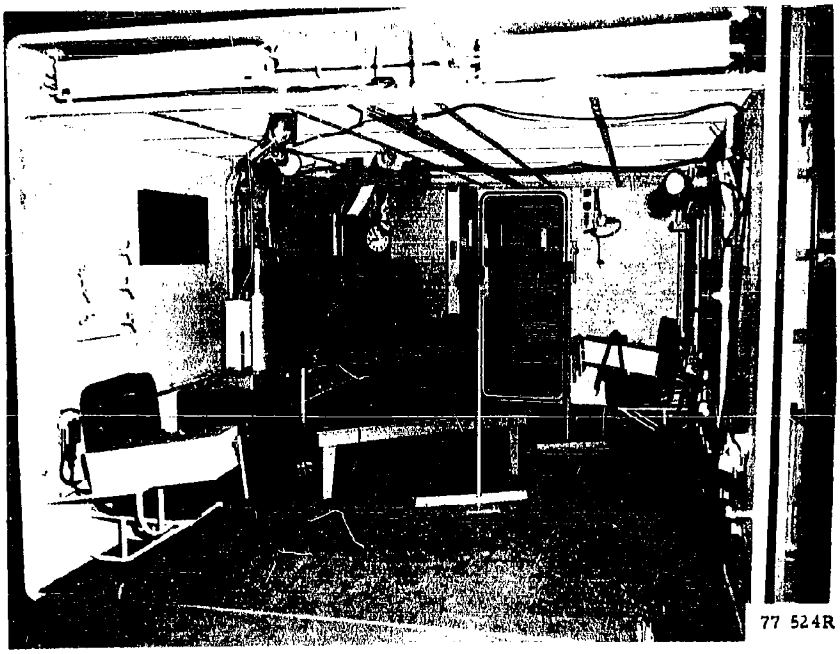


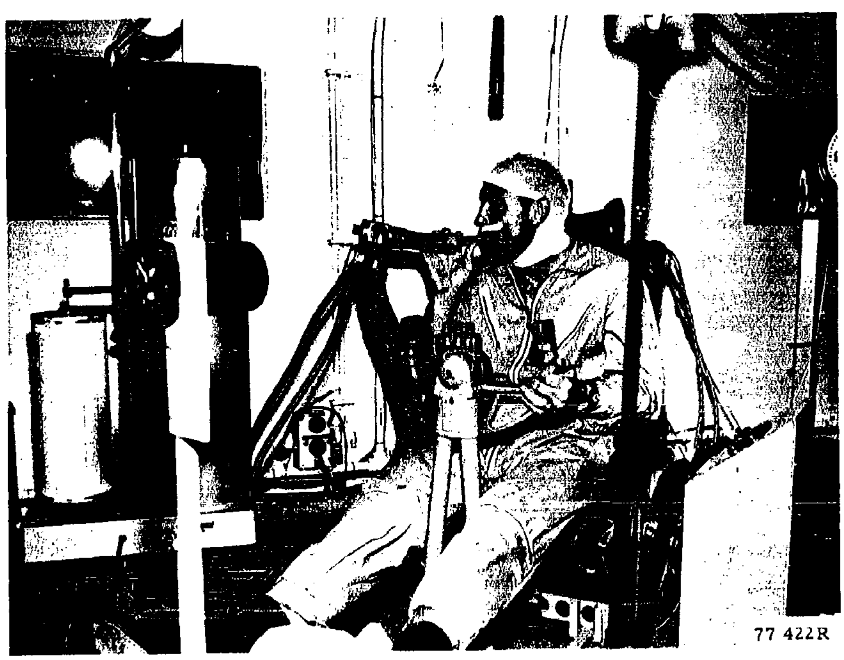
Figure 33 Preflight Examination
Lungs

Figure 34 Preflight Examination
Blood Specimen



77 524R

Figure 35 Test Chamber Prepared for Photography



77 422R

Figure 36 Calibrating Impedance Pneumogram with Spirometer

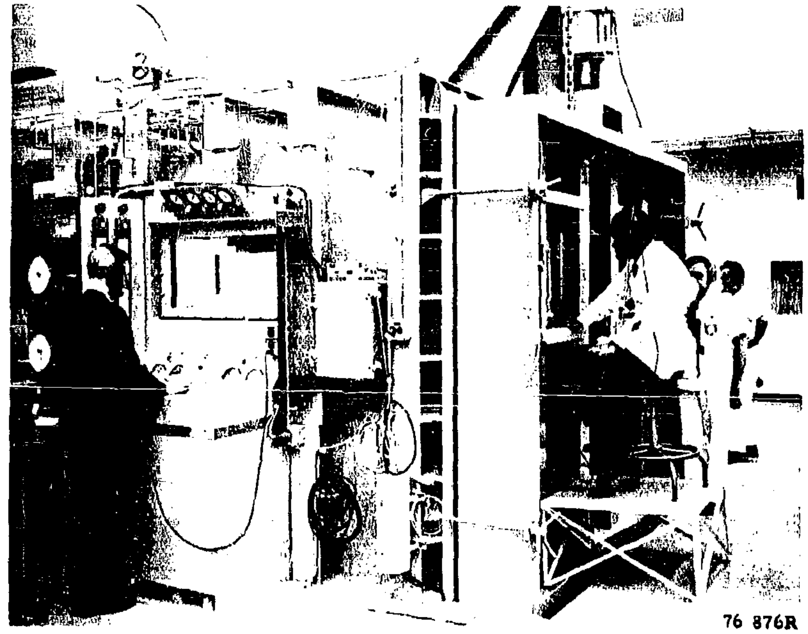


Figure 37 Flight Surgeon's and Chamber Operator's Stations

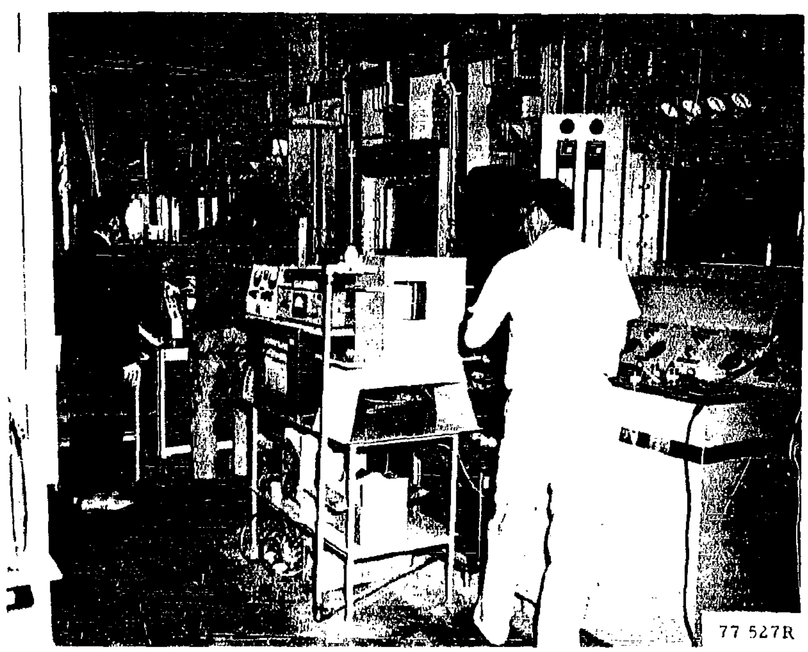


Figure 38 Instrumentation for Recording of Monitoring Data

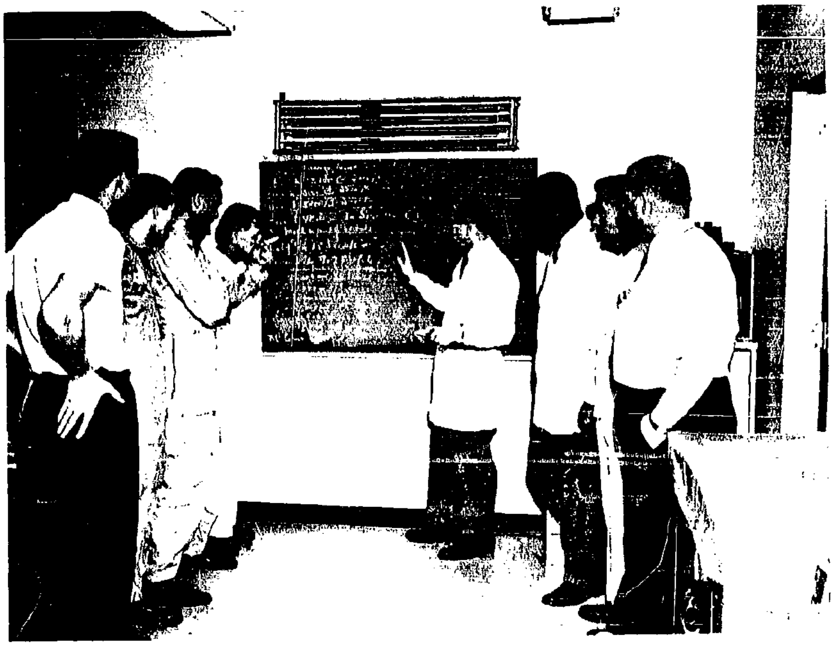


Figure 39 Preflight Conference of Key Personnel

TABLES

TABLE 1
RESPIRATION

TEST NO	ALTITUDE (feet)	RESPIRATION RATE (per min.)	AVERAGE TIDAL VOL. (liters)	MINUTE VOLUME (liters)	REMARKS
1.	8,000	24.6	.53	13.06	
	45,000 (1)	29.0	1.18	34.19	
	15,000	21.3	.63	13.44	Approaching altitude
		13.4	.49	6.51	Descending from 15,000 ft.
2.	8,000	24.8	.40	9.92	
	45,000	22.7	2.73	61.97	
	15,000	8.5	.76	6.46	
3.	Calibration data lost because of poor development of record				
4.	Spirogram and Visicorder records do not correlate				
5.	8,000	8.7	2.01	17.49	
	45,000	12.0	1.98	23.76	
	30,000	13.5	1.38	18.63	100% O_2 setting
		11.3	1.38	15.59	Diluter setting
	15,000	11.9	.96	11.44	
6.	8,000	20.7	.28	5.88	
	45,000	11.6	1.36	15.72	
	31,500	11.1	1.46	16.21	100% O_2 setting
	30,000	10.0	1.76	17.55	Diluter setting
	15,000	33.4	.83	27.69	
7.	8,000	31.6	0.56	17.70	
	45,000	21.6	1.80	38.88	
	30,000	45.5	.21	9.33	
	15,000	44.8	.26	11.65	
8.	8,000	28.7	.26	7.46	
	45,000	81.6	.49	39.82	Rate too rapid for accuracy
	30,000	20.8	.34	7.07	
	15,000	113.0	.01	1.09	Rate too rapid for accuracy

(1) 45,000 ft. is a nominal value

TABLE 2

OXIMETRY

TEST NO. 5				TEST NO. 7			
TIME (Sec.) FROM DECOMPRESSION	ALTITUDE (Ft.)	SCALE READING (Divisions)	OXYGEN SATURATION (%)	TIME (Sec.) FROM DECOMPRESSION	ALTITUDE (Ft.)	SCALE READING (Divisions)	OXYGEN SATURATION (%)
0	8,000	5.75	95.5	T-9 Min.	Ground	7.1	94
15.7	30,000	6.0	95	-8	Ground	3.6	98
31.0	-	6.0	95	-5	5,000	7.5	93
36.1	45,000	8.0	91.7	-2 Sec. at	8,000	7.7	92.5
48.0	45,000	13.0	82.5	0	8,000	7.8	92.2
60.0	45,000	15.3	72.5	4.5		7.8	92.2
73.0	45,000	17.0	65	5	45,000	8.0	92.
78.3	45,000	17.3	63	12.7	> 45,000	18.6	59.5
84.4		18.0	60	19.4		14.8	73
95		13.7	78	24.0		9.5	88
108		12.0	83	45.0		8.0	92
120		10.5	87	60.0		7.1	94
132		8.7	90.5	81.2	30,000	6.0	95
144	37,000	8.1	91.5	120		5.3	96.5
168		7.4	93	139.6	15,000	5.1	97
192		6.9	93.5				
196.5	30,000	6.6	94				
205		6.0	95				
351	15,000	6.0	95				

TABLE 3
TEMPERATURE

ALTITUDE (Feet)	TEMPERATURE AMBIENT °F.	BODY °F.	TIME	REMARKS
TEST 1				
8,000	70.5	-	0	Body thermocouple
45,000	13.0	-	18 Sec.	Causes interference in EEG & ECG signal
Start descent	28.0	-	1.7 Min.	
15,000	50.5	-	3.8	Level off
	72.0	-	4.8	Resume descent
"Ground"	91.5	-	9.4	Chamber air-conditioning not turned on
TEST 2				
8,000	66.5	-	0	Body thermocouple malfunctioning
45,000	8.0	-	30 Sec.	
	0	-	40	Recorder off scale
	0	-	58	Recorder back on scale
Start descent	25.0	-	79.2	
15,000	76.0	-	5.45 Min.	
"Ground"	76	-	10	
TEST 3				
8,000	72.5	-(1)	0	(1) Values incorrect, but did not change
45,000	49.5	-	5 Sec.	
15,000	79.5	-	5.5 Min.	
"Ground"	80.5	-	Approx. 8.5	
TEST 4				
"Ground"	61.0	95.6	T-7 Min.	
8,000	61.0	96.2	0	
45,000	22.0	96.2	12 Sec.	
	4.0	96.2	21	Minimum ambient
Start descent	7.0	96.2	27	
	61.0	96.2	65	Back to starting ambient
19,200	88.5	96.2	2.4 Min.	Holding altitude
	66.0	96.0	4.5	Resume descent
	69.5	95.2	5.5	Minimum body
	71.8	96.0	7.0	
"Ground"	71.5	96.2	11.0	
TEST 5				
"Ground"	72.0	97.5	T-2 Min.	
8,000	57.8	97.6	0	
	0	97.6	32.0 Sec.	Recorder off scale
45,000	$<$ 0	97.6	36.0	
	0	97.6	48.0	Recorder on scale

TABLE 3 (CONT)

ALTITUDE (Feet)	TEMPERATURE AMBIENT °F.	TEMPERATURE BODY °F.	TIME	REMARKS
Descent	29.0	97.6	78.3	
30,000	69.0	97.6	3.28 Min.	
15,000	71.0	97.6	5.85	
-	-	-	-	Recorder out of paper
TEST 6				
8,000	59.5	97.8	0	
45,000	25.0	97.8	37 Sec.	
Start descent	29.0	97.7	46	
30,000	67.0	97.4	2.73 Min.	
15,000	71.6	97.5	5.25	
"Ground"	69.5	97.4	16.0	
TEST 7				
8,000	63.5	96.4	T-1.5 Min.	
	66.0	96.4	0	
45,000	44.0	96.35	5 Sec.	
	30.0	96.2	22	
30,000	68.0	96.5	81.2	
15,000	76.5	96.6	2.33 Min.	
"Ground"	75.5	96.4	8.0	
TEST 8				
8,000	75.0	97.9	0	
45,000	26.0	97.9	5 Sec.	
	21.5	98.5	16	
30,000	78.5	97.8	84	
15,000	89.5	97.5	2.25 Min.	
14,500 (approx.)	79.5	97.4	3.32	Minimum body temperature
	78.4	97.4	5.68	
	78.3	97.4	6.5	
"Ground"	77.5	97.7	11.5	

TABLE 4
GALVANIC SKIN RESPONSE

TEST NO. 8

ALTITUDE	TIME	SCALE READING	REMARKS
Ground	T-15 Min.	4.0	Baseline
Ground	-	4-14.4	Changes during calibration of Imp. Pneumo--normal breathing changes during deep breathing.
		4-24	
Ground	T -8	4.4	Prior to take-off
	T -8 Approx.	44	Peak reading at takeoff
		3	A few seconds after above peak
To 8,000		2-21	Rapidly fluctuating changes
At 8,000		4.3	Min. value
	T -1	6.0	
	0	7.8	Rising, start decompression
	2	9	Start of rapid rise
At 45,000	6.2	49.5	Peak rise
< 45,000	12.5	12	Initial peak rise leveled;descending
	14	11.7	Start of fall
	16.1	6.8	End of fall
	16.3	11.7	Peak of rise
	17	4	Leveling a bit
	24	3.6	Min. rate of changes slowed
	48.3	9	Peak value
		4-10	20-30 Sec. cycles
22,000 Approx.	111	2-12	Abrupt cycle in less than 1 sec.
Level at 14,500	199	4-11	20-30 Sec. cycle pattern
Descending	381-389	5.5 to >60	Burst of activity during which curve went off scale for 0.4 Sec. Afterwards 20-30 sec. cycle pattern resumed.
	8 Min. Approx.	6 -1	$1\frac{1}{2}$ Sec. burst of negative activity
	8 1/3 Min. Approx.	7 -1.5	3 Sec. burst of negative activity and then back to cycling to end of test.

TABLE 5

SERUM AND PLASMA CHEMISTRY RESULTS

		PLASMA		SERUM			
DATE	IDENT.	HEMOGLOBIN mg%	CONDITION	SGOT Units	SGPT Units	LDH Units	CONDITION
	E.C.P.						
1-9-63	1	50.0	Sl.Hemo.	22	19	420	Sl.Hemo.
1-9-63	1	27.5	Straw-hazy	20	16	340	Straw-clear
1-9-63	2	22.5	Straw-hazy	19	8	355	Straw-clear
1-9-63	2	25.0	Straw-hazy	20	12	350	Straw-clear
Standard	-	21.5	-	-			
				(26-30)			
Control	-	19.0	-	30			
	E.L.H.						
1-17-63	1	40.5	Straw-hazy	20	11	440	Sl.Hemo.
1-17-63	1	37.0	Straw-hazy	17	11	400	Sl.Hemo.
1-17-63	2	29.0	Straw-hazy	18	14	330	Straw-clear
1-17-63	2	52.5	Sl.Hemo.	18	17	330	Straw-clear
Standard	-	21.5	-	-			
				(26-30)			
Control	-	17.0	-	27			
	J.W.						
1-28-63	1	18.0	Straw-hazy	19	12	330	Straw-clear
1-28-63	1	86.0	Mod.Hemo.	17	10	315	Straw-clear
1-28-63	2	18.0	Straw-hazy	20	13	325	Straw-clear
1-28-63	2	13.5	Straw-hazy	15	13	390	Straw-clear
Standard	-	21.5	-	-			
				(26-30)			
Control	-	19.5	-	26			
	R.M.J.						
2-12-63	1	24.0	Straw-hazy	16	17	290	Straw-clear
2-12-63	1	QNS	-	18	13	290	Straw-clear
2-12-63	2	24.0	Straw-hazy	22	19	270	Straw-clear
2-12-63	2	32.0	Straw-hazy	22	16	310	Straw-clear
Standard	-	20.0	-	-			
				(64-84)		(160-220)	
Control	-	19.5	-	84		230	
	P.D.						
2-15-63	1	190.0	Mark.Hemo.	25	21	290	Straw-clear
2-15-63	1	30.0	Straw-hazy	26	23	300	Straw-clear
2-15-63	2	39.0	Straw-hazy	22	18	480	Sl.Hemo.
2-15-63	2	89.0	Mod.Hemo.	25	18	380	Sl.Hemo.
Standard	-	21.0	-	-			
				(64-84)		(160-220)	
Control	-	18.0	-	84		230	

TABLE 5 (CONT)

DATE	IDENT.	PLASMA HEMOGLOBIN mg%	PLASMA CONDITION	SERUM SGOT Units	SERUM SGPT Units	SERUM LDH Units	SERUM CONDITION
	B.B.H.						
2-21-63	1	70.0	Sl.Hemo.	17	8	310	Straw-clear
2-21-63	1	58.0	Sl.Hemo.	13	9	310	Straw-clear
2-21-63	2	45.0	Straw-hazy	19	8	330	Straw-clear
2-21-63	2	32.0	Straw-hazy	15	12	400	Straw-clear
Standard	-	20.5	-	-			
				(16-20)		(160-220)	
Control	-	20.5	-	20		210	
	W.A.W.						
2-22-63	1	34.5	Straw-hazy	26	15	230	Straw-clear
2-22-63	1	37.0	Straw-hazy	25	13	250	Straw-clear
2-22-63	2	25.0	Straw-hazy	31	17	430	Mod.Hemo.
2-22-63	2	23.0	Straw-hazy	24	18	310	Straw-clear
Standard	-	20.0	-	-			
				(16-20)		(160-220)	
Control	-	20.5	-	19		170	
	L.K.						
2-26-63	1	32.5	Straw-hazy	20	18	410	Sl.Hemo.
2-26-63	1	36.0	Straw-hazy	16	16	240	Straw-clear
2-26-63	2	45.0	Straw-hazy	27	20	690	Mod.Hemo.
2-26-63	2	43.0	Straw-hazy	25	20	500	Sl.Hemo.
Standard	-	20.5	-	-			
				(16-20)		(160-220)	
Control	-	18.5	-	16		170	

KEY

Normal Values:

Lactic Dehydrogenase 100-350 Units

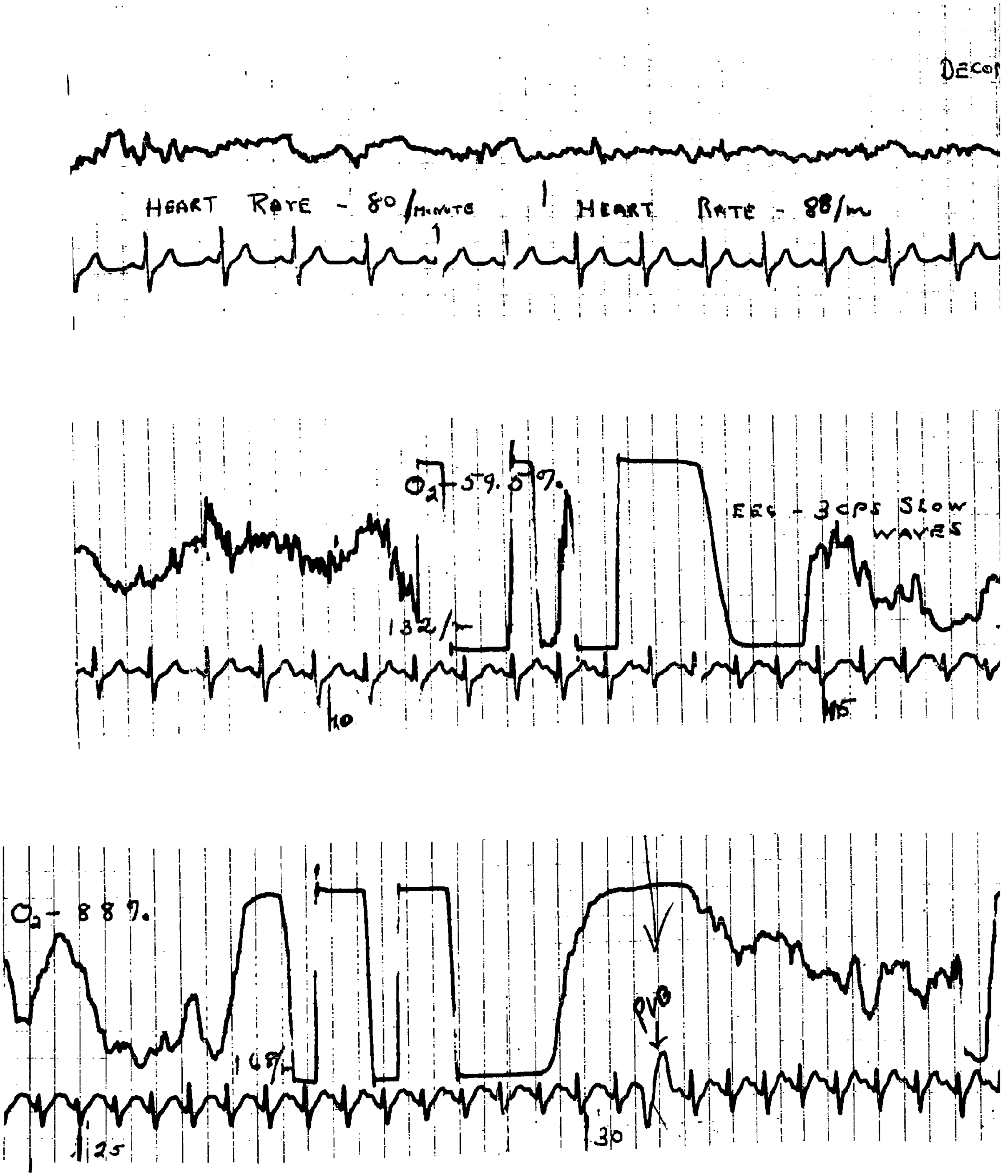
SGO-Transaminase 1-40 Units

SGP-Transaminase 1-35 Units

1 - Specimen prior to decompression

2 - Specimen after decompression

1



PHYSIOLOGICAL TRACINGS

TEST 7

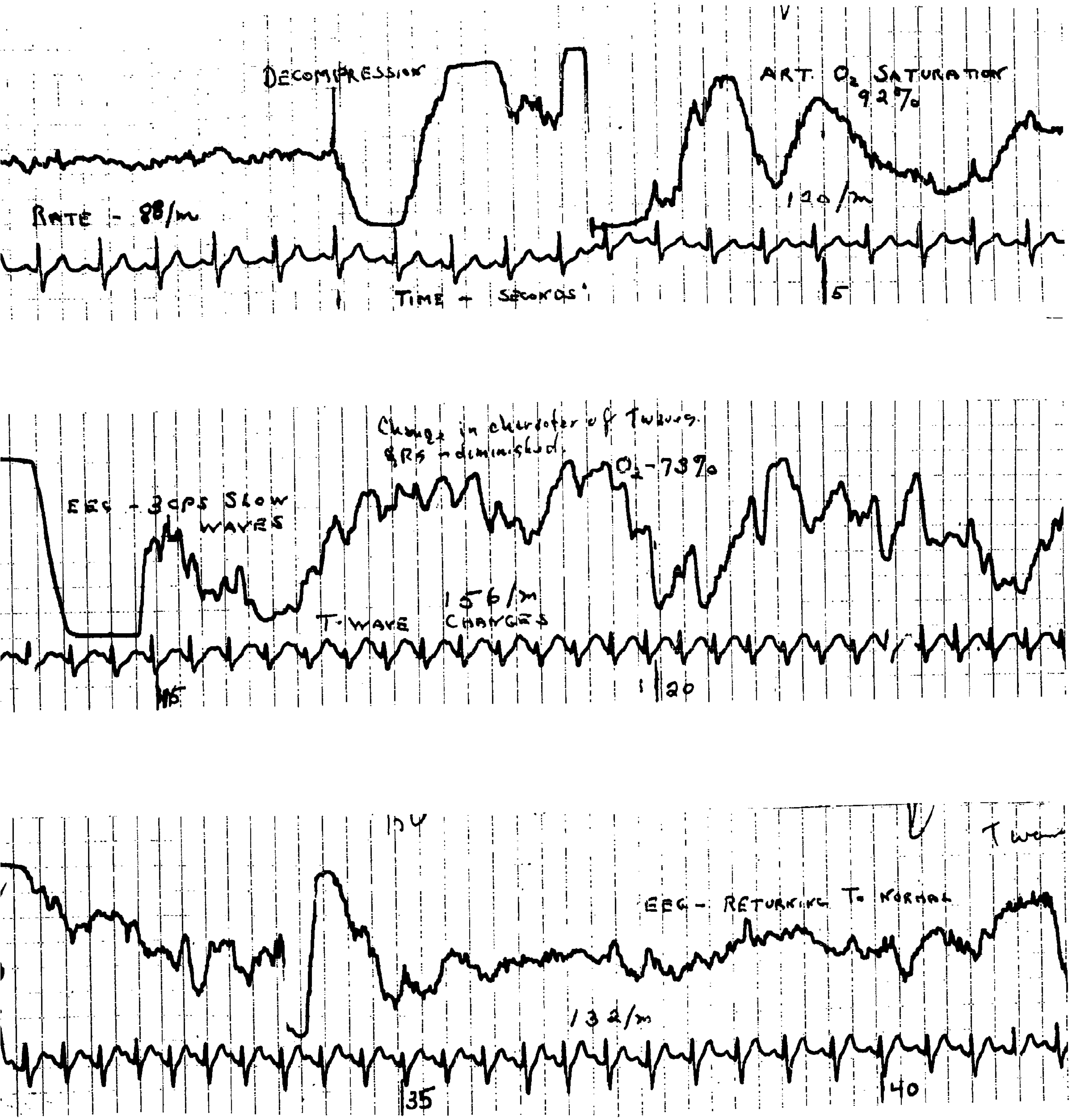


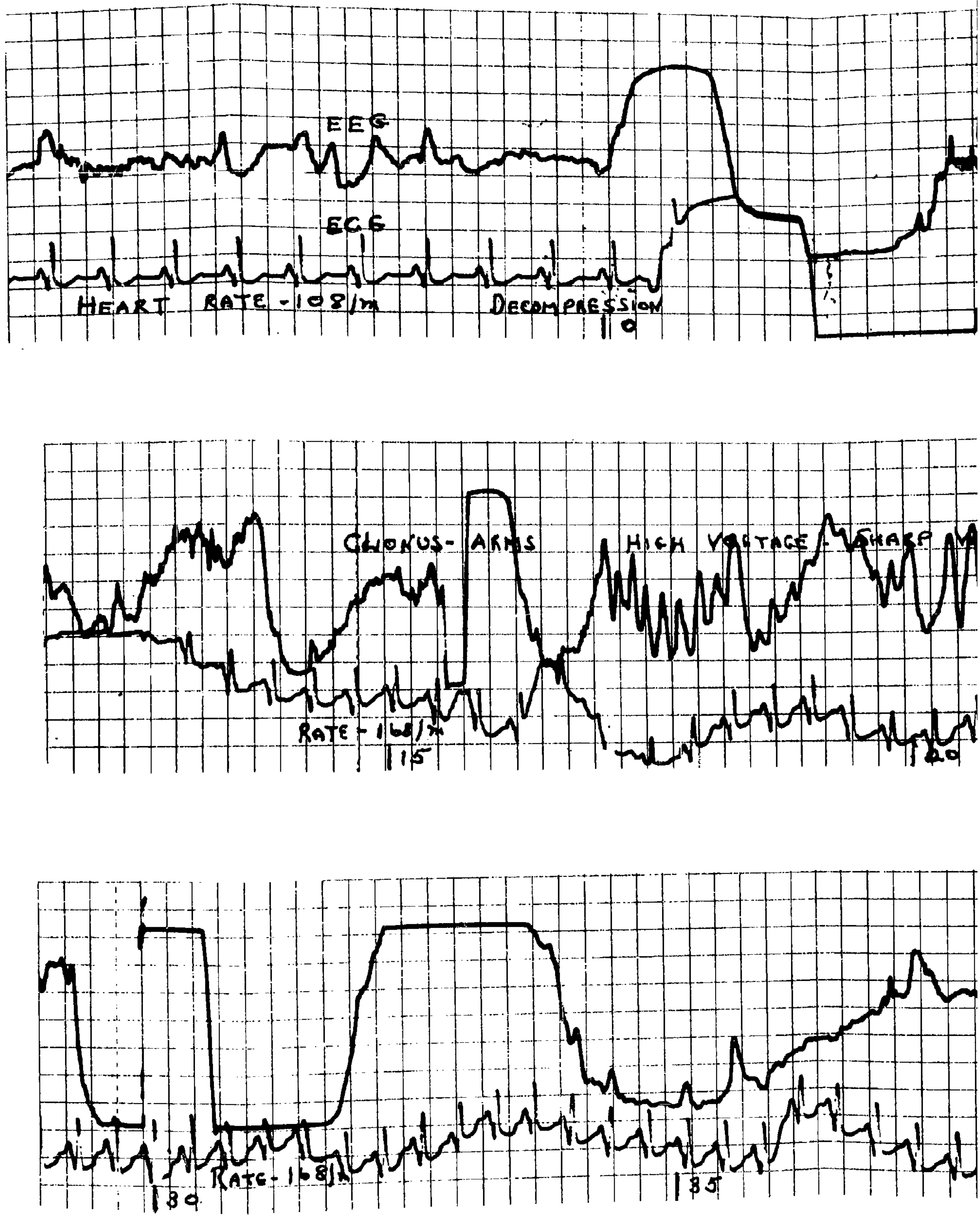
CHART SPEED 20MM / SEC.

OLOGICAL TRACINGS

TEST 7

2

1



PHYSIOLOGICAL TR

TEST 8

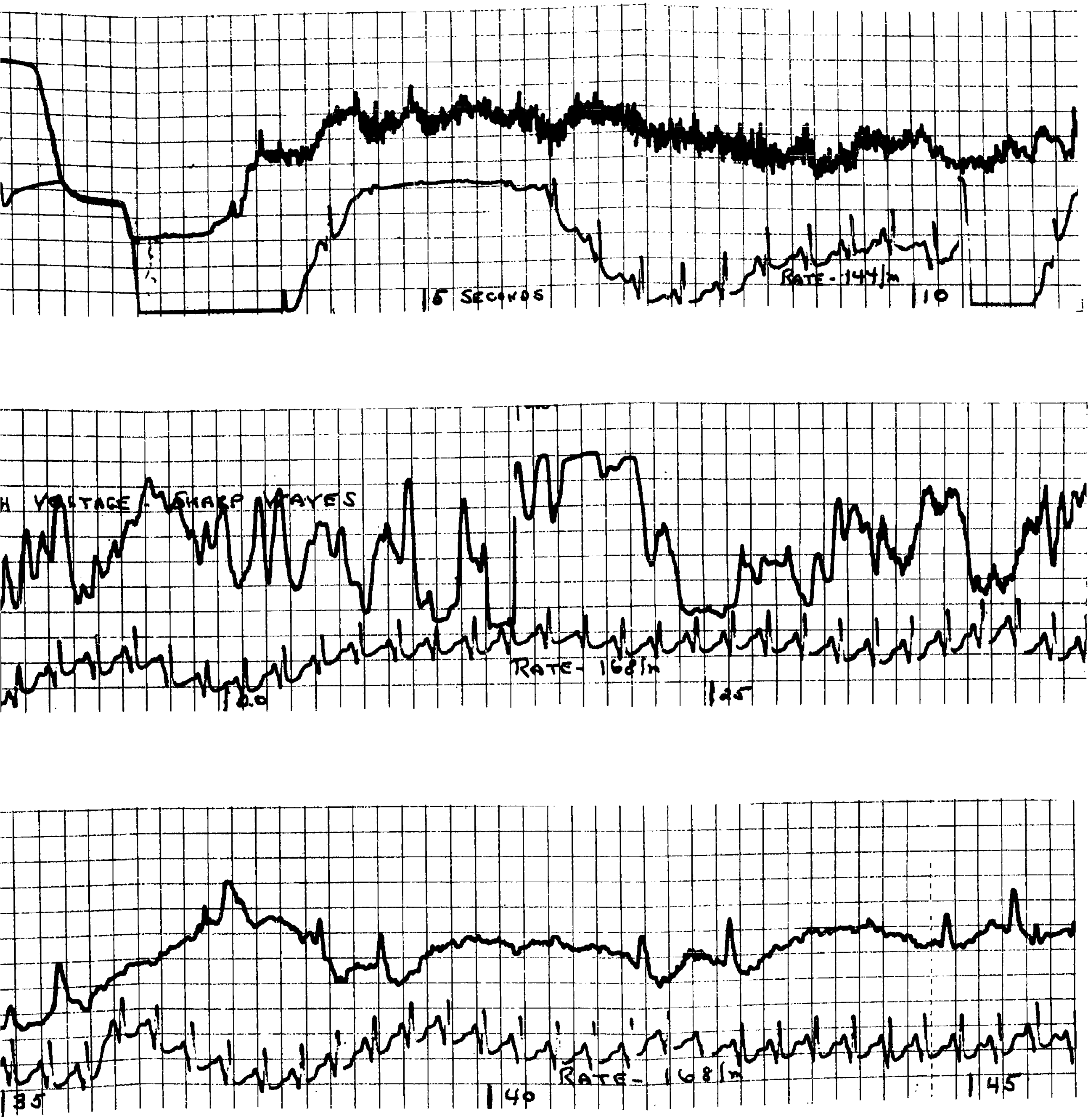


CHART SPEED 20 MM/SEC.

PHYSIOLOGICAL TRACINGS

TEST 8

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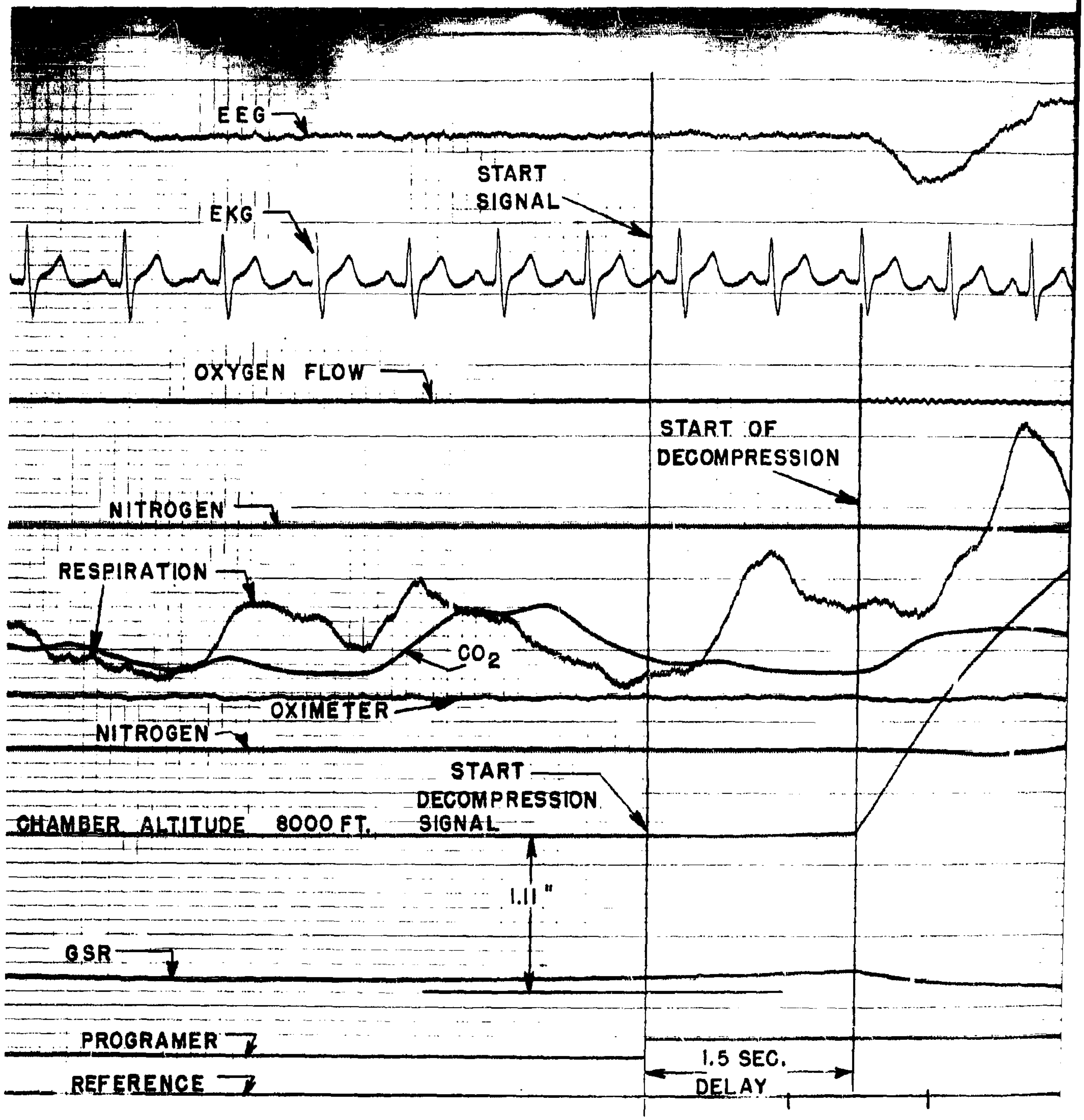
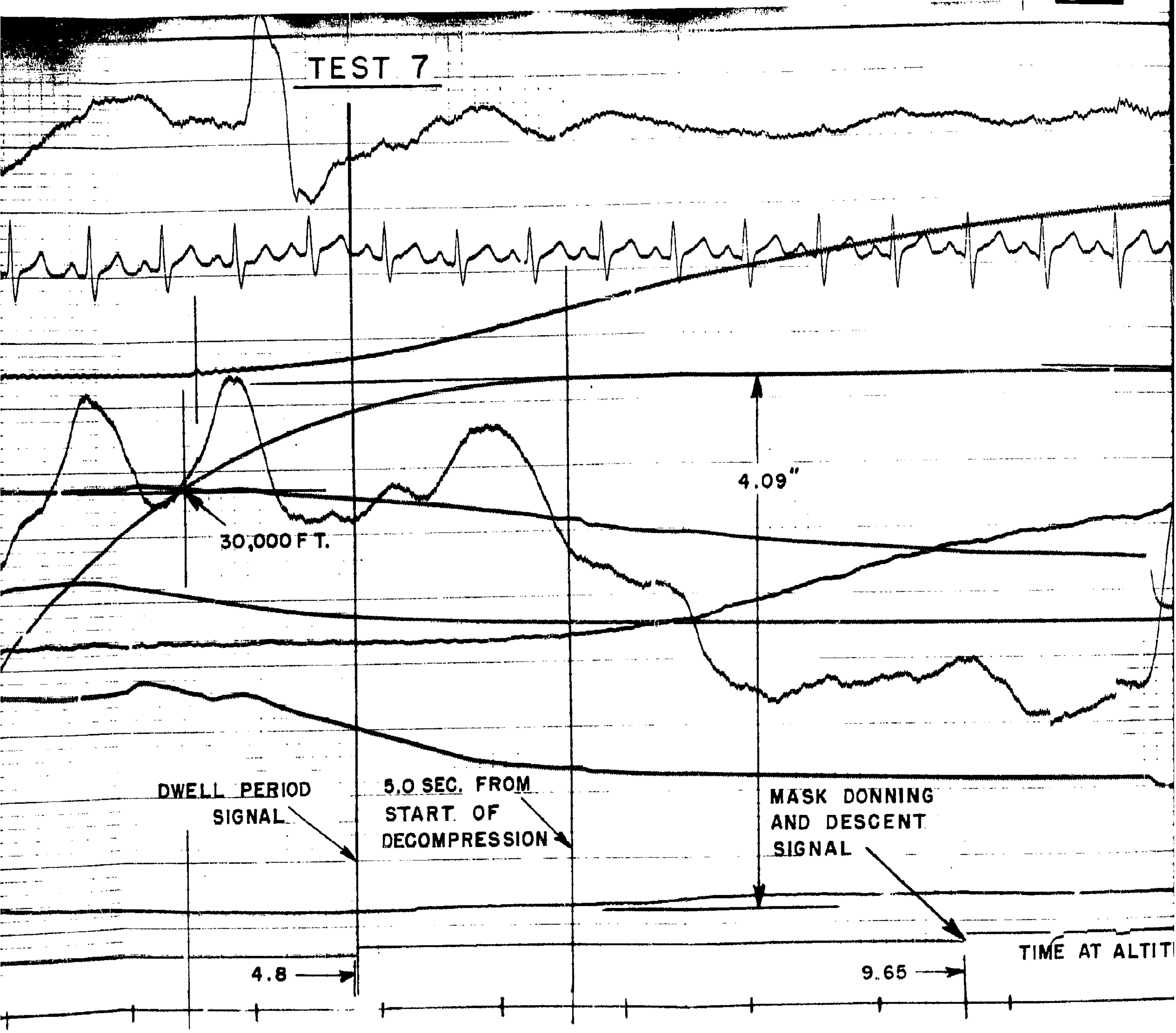
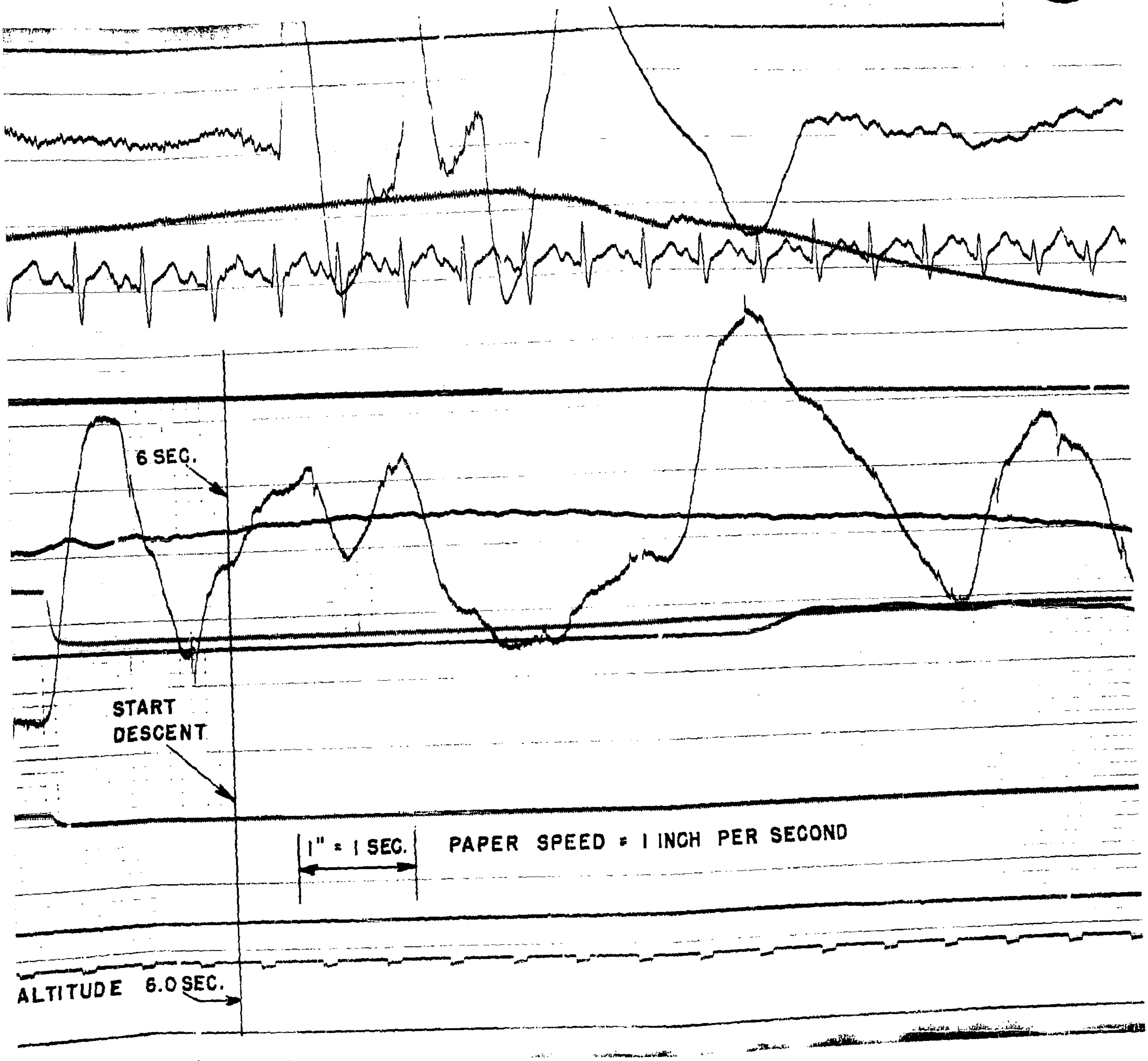
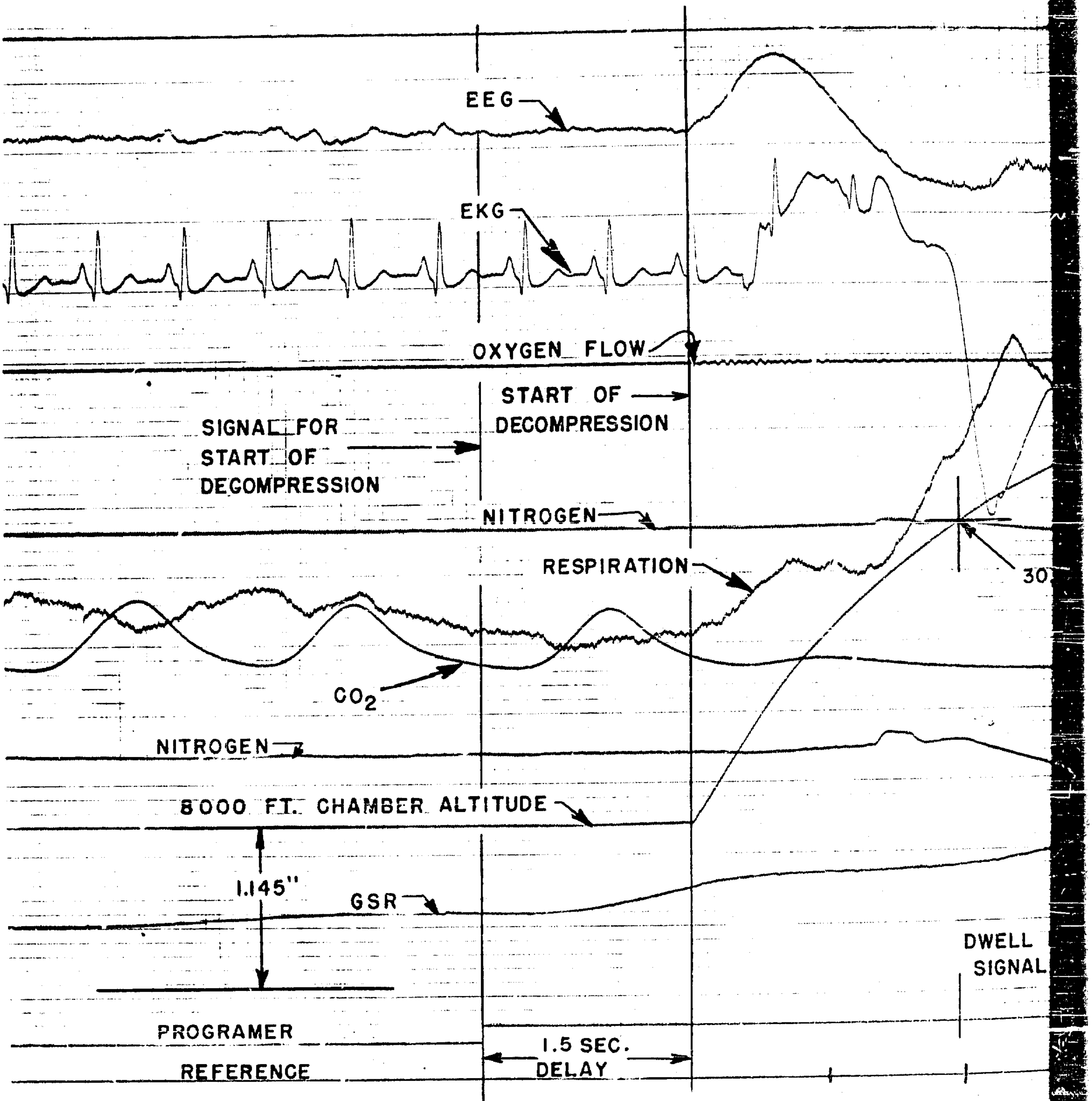

EEG
START
SIGNAL
EKG
OXYGEN FLOW
START OF
DECOMPRESSION
NITROGEN
RESPIRATION
CO_2
OXIMETER
NITROGEN
START
DECOMPRESSION
SIGNAL
CHAMBER ALTITUDE 8000 FT.
1.11"
GSR
PROGRAMER
REFERENCE
1.5 SEC.
DELAY

2


TEST 7
30,000 FT.
4.09"
DWELL PERIOD
SIGNAL
5.0 SEC. FROM
START OF
DECOMPRESSION
MASK DONNING
AND DESCENT
SIGNAL
4.8
9.65
TIME AT ALTIT

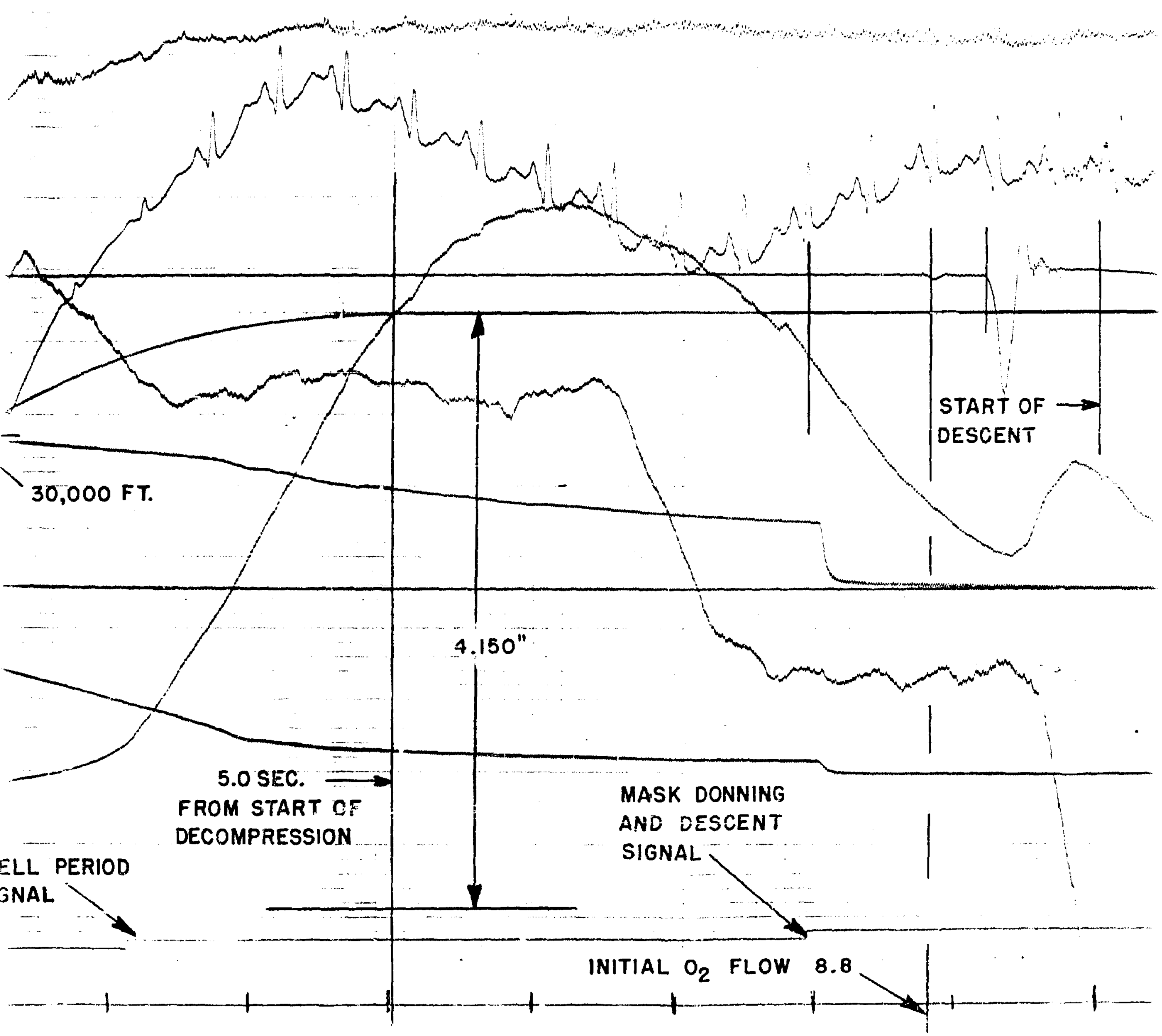
3


6 SEC.
START
DESCENT
1" = 1 SEC.
PAPER SPEED = 1 INCH PER SECOND
ALTITUDE 6.0 SEC.

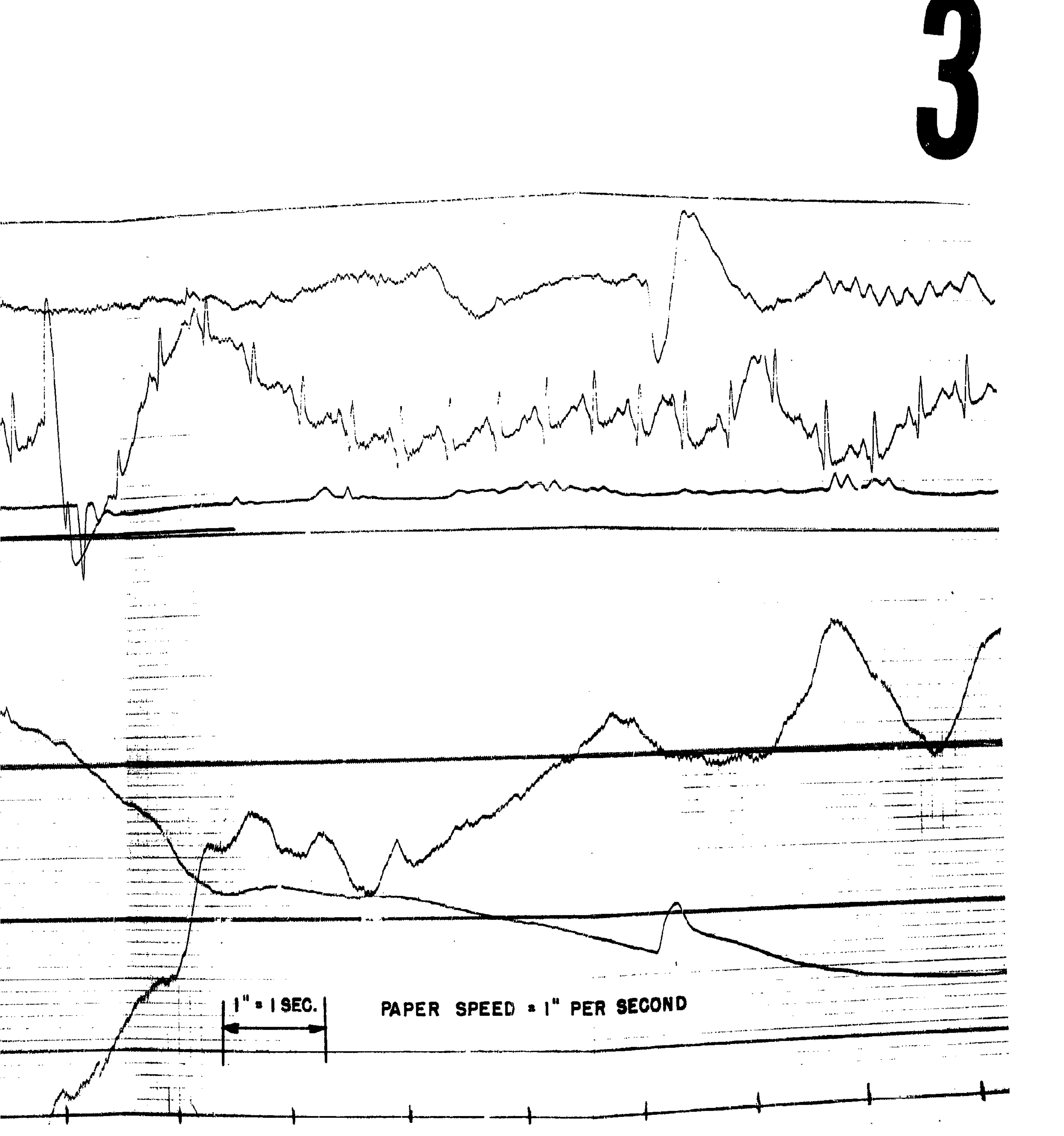

EEG
EKG
OXYGEN FLOW
START OF DECOMPRESSION
SIGNAL FOR START OF DECOMPRESSION
NITROGEN
RESPIRATION
30
CO_2
NITROGEN
8000 FT. CHAMBER ALTITUDE
1.145"
GSR
DWELL SIGNAL
PROGRAMER
REFERENCE
1.5 SEC. DELAY

2

TEST 8



30,000 FT.
START OF
DESCENT
4.150"
5.0 SEC.
FROM START OF
DECOMPRESSION
ELL PERIOD
NAL
MASK DONNING
AND DESCENT
SIGNAL
INITIAL O_2 FLOW 8.8


3
1" = 1 SEC.
PAPER SPEED = 1" PER SECOND

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